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ARMSTRONG'S PERSONNEL PROGRAM

A ten-point program activates the company's overall personnel project. Plan recognizes value of maintaining records of the human element just as accurate as those of more tangible business factors.

It is recognized generally today that the success of any business organization depends primarily upon the spirit, ability, and effectiveness of the persons associated with it. Competing companies generally have about equal access to money, machinery, and materials, so that almost invariably it is the company with the best men, the most satisfied employees that forges ahead. Industrial leaders are devoting more and more attention to the development of an active, carefully organized personnel program as one of the basic necessities for successful business operation.

The Armstrong Cork Company has long been recognized as a leader, and something of a pioneer, in the field of personnel administration. This company started in Pittsburgh in 1860 as a tiny plant for cutting cork stoppers for bottles. Through the years it expanded, and new products were added to the Armstrong line—metal and plastic closures for jars and bottles, linoleum and other hard surface floorings, corkboard insulation and a wide variety of building materials, textile roll coverings, shoe products, and many others. Then, in 1938, so that the company could offer a complete package," Armstrong bought the Millville, N. J., glass plant of the Whitall Tatum Company and the Dunkirk, Ind., plant of the Hart Glass Manufacturing Company.

Three of fifteen employees of the Millville, N. J., glass plant of the Armstrong Cork Company with service records of 50 years or longer. The photograph, taken at a recent dinner held in honor of the fifteen, shows Harry Brown (center), who has worked in the plant for 60 years; and identical twins, Harvey and Howard Wallace, each with 50 years of service.

The company's progressive personnel program and the employee benefits existing under it were applied immediately to these two new members of the organization, even to the extent of recognizing the old employees' years of service in computing retirement benefits.

The fundamental objective of Armstrong's personnel policy is found in its frequently repeated theme, "We want our company to be one with which we may be proud to be associated and one for which men and women want to work." The company's leadership in the field of management-employee cooperation stems from a constant and conscientious effort to carry out this theme in actual practice.

The primary tools for activating the theme are represented by Armstrong's ten-point personnel program:

1. The company is determined to have associated with it—in each position—the most capable individual available.

2. The company seeks to train thoroughly each of these carefully selected individuals so each may become increasingly effective in his position.

3. The company seeks to provide security of job and income for each employee.

4. The company is committed to pay each employee a fair wage for work performed.

5. The company seeks to provide safe and orderly workplaces for each employee.

6. The company seeks to instil in each employee pride in the policies, products, and progress of the company.

7. The company seeks to provide each employee with reasonable working hours, affording enough time for relaxation.

8. The company seeks to provide each employee with knowledge of what the company is doing, and an opportunity to express his opinions freely.

9. The company seeks to provide for each employee an opportunity to be prepared in case of sickness, accident, disability, or death, and to provide an income for his declining years.

10. The company seeks to provide for each employee some measure of protection against unavoidable periods of slack work.

But these ten ideals, though they represent the skeleton of Armstrong's personnel program, are, at best, only the framework on which management-employee relationships are hung. The program as a whole is made to work by the specific practices and activities that have been developed to round out the basic ten-point plan.

The Personnel Department responsible for carrying out Armstrong's detailed program is headed by a General Personnel Manager who reports directly to the President's office. This Department determines general policies and acts as an advisor to the eighteen plant personnel departments that function in the individual factories.

Armstrong's present personnel program has existed since 1937 when the General Personnel Department, seeking to modernize and improve its policies wherever possible, solicited opinions and suggestions from approximately 10,000 employees with a down-to-earth questionnaire entitled "How Do You Feel?" This questionnaire listed specifically the various ways in which the company was striving to aid the individual worker and then sought comments as to how well the program was succeeding and how it might be changed to the greater satisfaction of the employees.

Results of the survey indicated that some employees felt that the company was not keeping its workers sufficiently well informed of developments within the organization, that the company should make a greater effort to keep its employees abreast of policies and practices.

Recognizing this as a logical criticism, the Personnel Department took immediate steps to improve its facilities for dispensing information. Obviously, there were two methods of transmission available—personal contact and published reports. The Department decided to use both media.

Since every man has a right to expect his supervisor to keep him reasonably well informed, and since workers will turn to the right type of supervisor for information and advice, Armstrong started its new personnel program by revising its training program for supervisors. In years past supervisors had been trained by instructors from outside the organization. Though this training was unquestionably worth while, it lacked the intimate and practical touch of dealing with the actual problems of supervision within the Armstrong Cork Company.

Consequently it was decided to develop a special company training course under the direction of permanent members of the Armstrong organization. In developing this course, a leaf was taken from the notebook of Armstrong's sales training program which had already been in existence for more than 20 years. Under this program young men had been recruited each year, chiefly from the graduating classes of colleges and universities across the nation, to be trained for sales positions. These young men were brought to the company's General Office in Lancaster, Pa., for a period of orientation and instruction of approximately six months before receiving field training. At the completion of his training and following assignment to the field, each man returned to the Home Office for a "Postgraduate Week" at least every other year. By frequent personal contact and by careful initial training these salesmen became well grounded in their job requirements and had an opportunity to absorb the fundamental principles which actuate the company's business.

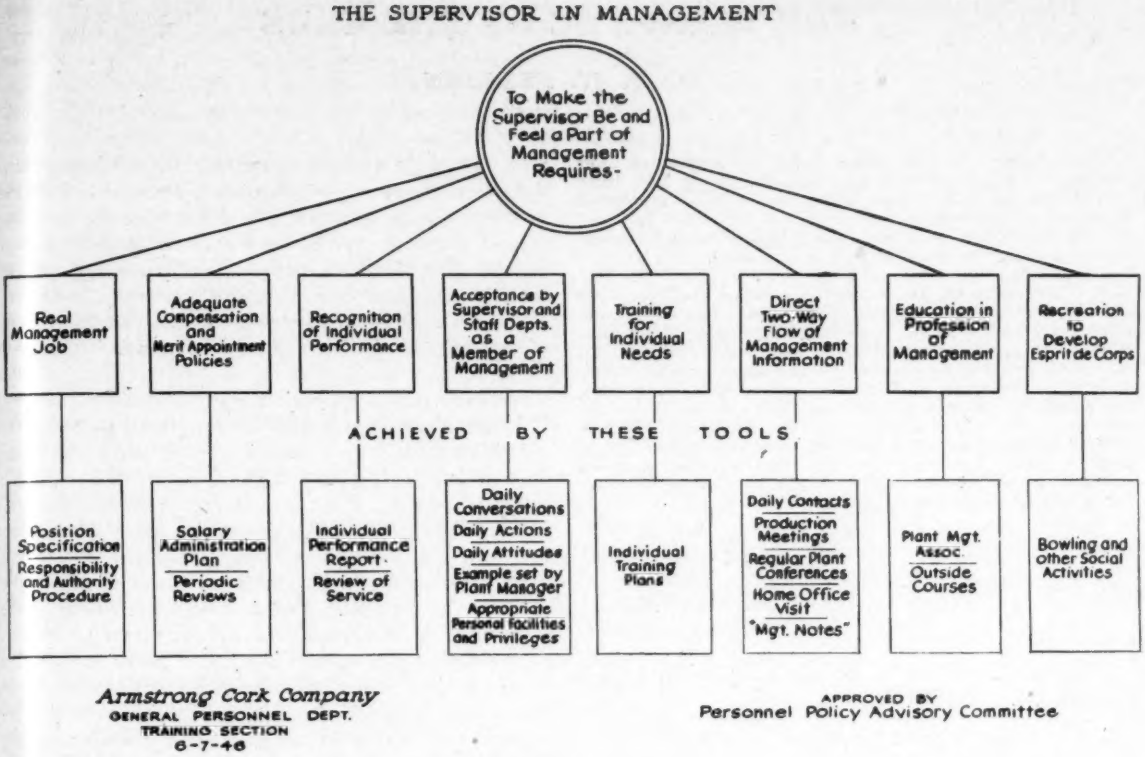
In contrast to the salesmen, many operating supervisors had never seen the General Office, had never met the officers of the company. For these supervisors a program referred to as "Home Office Week" was inaugurated, and more than 500 men, in groups of about fifteen, came to the General Office for a week's stay. Seated around a table in the Boards of Directors' Room, they met and talked with the head of every staff department and the executive officers, including the president and the chairman of the board. This Home Office Program has continued, and approximately one-third of the company's supervisors return to the General Office each year for a week's review.

A second and most important phase of training is the program of Plant Conferences. Under this program leaders from the General Personnel Office during the fall, winter, and spring months visit each factory every three weeks for conferences with supervisory groups. Subjects discussed at these conferences are all selected by members of the groups themselves. The assistance of these supervisory conference groups is sought in the development of company policies, thus assuring that these policies are understood and supported by the men who administer them. "Management Notes," a record of interesting company and national affairs, written for supervisors, is sent each month to all conference members.

To aid in training and developing new supervisors the company has produced a series of inter-related forms known as "The Supervisory Six." These six media are designed for utilization with individuals, in contrast to group programs, and can be used for the training of any supervisor, in office or factory, in line or staff, and at any level. A short description of each of "The Supervisory Six" follows:

1. The Position Specification. Before a supervisor can begin to function successfully, it is imperative that he know what is expected of him. This knowledge must be given in an organized manner and not through a hurried, generalized conversation. The Position Specification is an orderly presentation of the general and specific responsibilities of the supervisor's position as prepared by his immediate superior. It presents a ready basis for review in case of changed responsibilities, and it serves as a written reference for use by the individual at any time. It is not in any sense restrictive, but is written in such a manner as to stress the scope of the position and its value to the company.

2. The Degree of Authority Procedure. An effective



A graphic outline of Armstrong's employee relations set-up.

organization requires well-defined relationships among all individuals, particularly between the supervisor and his superior. Unless these relationships are established definitely, experience proves that responsibilities may unintentionally not be fully assumed, "buck passing" increases, and the general tempo of organization action decreases—primarily due to lack of understanding. The extent of "go ahead" must be defined by the superior, be done on an individual basis, and fully appreciated by both the superior and the supervisor. It is obviously desirable to have these working relationships clearly understood at the outset rather than endure the lengthy period of time required to have them become established through working experience on the job. Under the Degree of Authority Procedure the superior discusses in detail each responsibility assigned to the supervisor and records on a prescribed form the degree of authority he expects the latter to exercise. Generous use of case illustrations helps to define clearly working relationships and, as a result, the supervisor has a definite record for his guidance.

3. The Supervisor's Performance Report. It is only human for a supervisor to direct his effort and attention to those points where the greatest pressure appears to be exerted at the moment, but this gives a disproportionate amount of attention to certain items and impairs the equilibrium of overall control. It is just as normal for a supervisor to devote the major share of his attention to those things which he has reason to believe are uppermost in the mind of his superior. Consequently the superior should cover periodically the agreed upon scope of responsibility with each individual supervisor and with him determine the relative importance of each function assigned, as a guide to correct allotment of supervisory time and attention. As a means of facilitating and assuring that this is accomplished, the Supervisor's Performance Report is introduced. This form is designed to present on one summary sheet the record of performance of the major responsibilities of the supervisor, and trends become evident as facts are entered periodically. Included in the report are cost factors, quantity produced, quality achieved, labor turnover rates, absenteeism, grievances, accidents, suggestions received, and other items pertinent to the control of the operation. The frequency with which it is used—monthly, weekly, etc.—the specific items included, and the extent to which it is applied are determined by individual situations.

4. The Review of Service. The development of a supervisor to his full effectiveness—an objective of value to both the individual and the company—requires a periodic, comprehensive evaluation of his total performance and potentialities. If the maximum gains are to be secured, this evaluation must be done in factual terms to provide the basis for positive action. Armstrong's Review of Service plan consists of two basic steps. First, an analysis of a supervisor's performance and a plan for future development are made by his immediate superior, and second, this analysis and plan are discussed in detail with the individual. In making the analysis the superior sets forth his opinion, with supporting facts, of the performance of each responsibility, notes special traits, experience, and aptitudes, and summarizes not only strong factors, but those which might be further strengthened. The final step of the analysis is to list suggestions and plans for the supervisor's further development. In the second phase, the interview, the superior discusses the

(*Continued on page* 462)

THE WARFARE OF THE GODS

By F. W. PRESTON

Editor's Note: So that there would be maximum news coverage of Operations Crossroads, the Army and Navy issued invitations to attend the bomb tests to a selected group of publications in specific fields. The Glass Industry was chosen to represent the glass field and John T. Ogden attended the first bomb explosion at Bikini. Dr. Preston was present at the second test.

It is impracticable for a monthly journal like The Glass Industry to compete with the daily press, the radio commentators, or the movie newsreels in picturing the blasts: nor was it possible for either of our emissaries to learn much of specific importance to the glass manufacturer. This may come later. Both Mr. Ogden and Dr. Preston are scheduled to report their personal experiences and reactions to the Glass Division of the American Ceramic Society at the Columbus meeting later this month (September 14th), but meantime Dr. Preston sent us some ruminations on atomic bombs and thunderstorms which we felt might be of interest.

July 26, 1946
(Bikini Date)

Writ aboard the
U. S. S. Appalachian

I am in the position of Ben Backstay, when he fell overboard.

"They threw him out some tackling
to give his life a hope,
But, as the shark bit off his head
He couldn't see the rope."

The bomb went off, and I suppose it damaged some glassware: or maybe the glassware stood up remarkably well. But as the ships near the blast are at the bottom of the Lagoon, and those that floated are so "hot" with radioactivity that they cannot be visited, I haven't been able to find out.

Off the coast of California for eight hundred miles there is a nearly continuous blanket of quilted cloud, a thousand feet or so above the sea. Beyond that, as one nears Hawaii or continues on to Kwajalein and Bikini, the cloud structure is more open. The whole skyscape is dotted with cumulus clouds, mushrooming up here, there and everywhere, not unlike (though not entirely like) the atomic bomb cloud itself. This suggests some comparison of "thunderclouds" and atomic experiments.

The energy released in an atomic bomb explosion is about 10^{21} ergs. This is no secret, for the fact has been announced many times, but usually in an indirect language. For instance, President Truman declared the bomb to be equivalent to about 20,000 tons of T.N.T., and the heat of combustion of T.N.T. is known, being around 1,000 calories per gram of the explosive, and a calorie is 4.2×10^7 ergs. The information may also be deduced from the Smyth Report, which places the mass of uranium in the bomb at between 1 kilogram and 100 kilos. This leaves us some latitude, but the other published data lead us to suspect that the mass disappearing in the reaction is about 1 gram, which is equivalent, by the Einstein equation[1], to about 0.9×10^{21} ergs. Or again we have Commander Revelle's statement that if all the energy of the bomb were used to heat the water of Bikini lagoon, it would not raise the temperature of a square mile of the lagoon by as much as one degree. The published maps of the Hydrographic Office show that the lagoon is somewhat uniformly about 170 feet deep, so Revelle's statement means that the energy of the explosion is well under 10^{22} ergs and is probably about 10^{21}.

Now 10^{21} ergs is approximately 36,000,000 H.P.-hours. It is enough to keep a fifty-thousand horse-power plant going for a whole month: it is enough to drive a large liner or battleship at normal cruising speed completely round the world. If we assume that in current practice it takes eight million B.T.U. to melt a ton of glass, then the energy of an atomic bomb would run a medium sized glass-melting tank, making 70 tons of glass per day, for six months[2]. That is how much energy there is involved in the annihilation of one gram of matter.

We shall, however, probably get a better perspective on the subject, and a more balanced conception of the size of the bomb, if we compare it with natural phenomena with which we are thoroughly familiar, rather than by trying to visualize 20,000 tons of T.N.T. going off at once. Few, if any, of us ever expect to see that experiment, and it is describing the unknown in terms of the equally unknown. It seems to me better to describe the bomb in terms of the thunderstorm, for almost all of us have seen thunderstorms, and most of us see many of them every year. Moreover, the thunderstorm occupies a unique place in our minds: we never tire of it: we always admire it: we are not strictly enamored of it, but we rejoice at its magnificance, we regard it with a mixture of reverence and awe, we are normally both frightened and uplifted. Historically, for Aryan and Semite alike, the thunderstorm is the physical embodiment of the Lord of Heaven, the clothing and panoply of the chiefest of the Gods.

The winged bulls of Assyria are graven images of the thundercloud, and the cherubs that guarded the ark of the covenant are the same thing. For a cherub is not a fat-bellied baby on inadequate wings: it is a towering creature on gigantic pinions, with a voice of thunder, and dealing death by lightning. Thus the two cherubs that guarded the ark of the covenant stood fifteen feet high and had each a wing-spread of fifteen feet, and the sacrilegious sons of Aaron perished by lightning at their hands.

And this perhaps also is the riddle of the Sphinx, half god, half lion, a graven image of the thundergod, in a land that scarcely knows a thundercloud.

The ten commandments were uttered in a voice of thunder on Sinai and engraved upon stone by the lightning, while a terrified encampment of Israel cowered in the valley below; and perhaps the golden calf that Aaron, or Jeroboam, made, would have been a winged bull if gold had been sufficient to model the grown animal. It was not till the time of Elijah that the still small voice replaced the thunderstorm as the voice of God.

[1] $E = mc^2$, where E is energy in ergs equivalent to a mass of m grams and c is the velocity of light $= 3 \times 10^{10}$ cm/sec.
[2] 1 B.T.U. = 252 calories = approximately 10^{10} ergs.

About the time that Moses communed with the thunder-god on Sinai, the Aryans were pouring through Khyber Pass into India. There they settled the vast plains of Indus and Ganges, with the Himalaya towering on their north. There the terrifying display of Sinai was multiplied a million fold for in all terrestrial creation there is no such display of might as comes each year on that climatic day when Indra wheels his massed artillery against those stupendous ramparts and the monsoon breaks upon the roof of the world.

Greece and Rome concurred in this, that the chief of the gods is he who wields the thunder. Jupiter is not the oldest of the gods: Saturn is older. But Jupiter Tonans, the thunderer, is president of the host of Olympus: to him the other gods, and goddesses, must ultimately appeal, and ultimately submit. Vulcan may sometimes stage a good show with Vesuvius or Stromboli, but he is but a lame god, a comic opera god, of whom even his wife is a little ashamed. But she does not take the thundergod lightly.

We may see in all this the working of the basic primitive human mind: we see it in savages in ancient cultures, and in modern ones. Psychologically it is no doubt based on the fact that a tiny child, savage or civilized, is afraid of only two things, and one of them is a sudden loud noise; and the greatest of such noises is the thunderclap. In this respect, all religions have their final psychological bases in a primitive and basic instinct.

We may now turn to the physics, rather than the psychology, of thunderstorms.

To evaporate a gram of water at ordinary atmospheric temperatures requires 600 calories or 2.5×10^{10} ergs. Conversely, when a thunderstorm precipitates liquid rain from invisible vapor, it releases 2.5×10^{10} ergs for every gram of water precipitated.

We measure rainfall in inches of precipitation, and many a thunderstorm lays down more than an inch of rain. Sometimes it does not take it many minutes to do so.

Now if an inch of rain falls over an area of a square mile, the number of grams of water is easily calculated, and from this we can compute the energy released. It comes out as 1.5×10^{21} ergs. This is equivalent roughly to one atomic bomb, perhaps nearly equal to two.

Now the area thoroughly devastated by an atomic bomb is probably at least a square mile, so we do not need to drop such bombs in a pattern closer than one to a square mile. In such a pattern they would be equivalent, in energy released, to an average good thunderstorm.

There are differences, of course. Most of us would prefer the thunderstorm to a bombing on such a basis. We have a healthy respect for Jupiter Pluvius, even Tonans, but our respect for the Manhattan District is the respect we accord to the devil. Well-named is Plutonium, the material of the god of the underworld.

One principal difference between the storm and the bomb is the fact that the storm normally releases most of its energy in the upper air, where we earth-bound creatures encounter little of it. Another is the fact that the energy of the storm is released more uniformly over the area, and has no centers of intensity comparable with that in the immediate neighborhood of the bomb explosion. The storm does not lay down a poisonous pall of radioactive fission products, slow-enveloping, insidious and sinister shroud of death. Finally, though, the storm may release more energy than the bomb, it takes considerably longer to do it, minutes at least, in place of seconds or fractions of a second.

These are differences, and important differences; but the similarity in total energy, per square mile, of the bomb and the storm, is our point at the moment.

The annual rainfall at Bikini Lagoon is not yet known. It seems reasonable to suppose it may be quite similar to that at Ujelang, also in the Marshall Islands. Here the rainfall averages about 83 inches per annum, and as much as 11.7 inches has been recorded in a 24-hour period.[3] Bikini Lagoon is about twenty miles long and averages ten miles wide from north to south. Its area is therefore about 200 square miles. With a rainfall of eighty inches or more per annum, it follows that the rain is equivalent, in energy released, to some 15,000 or 20,000 atomic bombs per annum, or an average of fifty atomic bombs a day—one every half hour, the year round. Such is the scale on which nature works at Bikini, and such the scale on which Admiral Blandy and Joint Task Force One operated. King Juda[4] should be glad that Jove looses his bolts upstairs, and not where Blandy placed his.

What then must be the scale of operations when Indra assaults the thousand mile chain of the Himalaya?

The energy received by the earth from the sun, at the top of the atmosphere, amounts to about 1.9 calories per minute for every square centimeter of area. This figure is known as the "Solar Constant." The disc of the earth, 8,000 miles in diameter, has an area of 1.27×10^{18} square centimeters.[5] The energy received by the whole earth per minute is therefore 10^{26} ergs, or the equivalent of 100,000 bombs per minute.

This is Jove's ultimate arsenal, from which he manufactures his lightning bolts. This is the source of the fire and fury that blasts from the muzzles of Indra's levelled guns from Kashmir to Assam. From this stock, too, the nameless gods of the Andes draw their power, and send the floods of the Solimoes each year to swamp the vast Selvas of the Amazon, earth's greatest river system. Here, also, are replenished the black clouds shadowing with wings the land beyond the rivers of Ethiopia, sending their waters to the rainless vale of Egypt from sources known of old only to the Sphinx, whose enigmatical smile is perhaps that of the god of the storm-cloud, knowing more than mortals about these things.

The Sphinx is smiling perhaps at the big bad bombs of Bikini, for he knows what a real arsenal is like.

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[3]Sailing Directions for the Pacific Islands, Vol. I, p. 575. U. S. Hydrographic Office, #165 (1938).

[4]Chief of the Bikini natives.

[5]This is the cross section of the earth, of course, not the surface of the earth: πr^2, not $4\pi r^2$.

• Robert F. Walker, formerly with the Owens-Illinois Glass Company's Streator, Illinois, plant, has been transferred to the company's plant in Gas City, Indiana. Mr. Walker is acting in the capacity of supervising industrial engineer. He worked at the Alton and Streator plants for thirteen years, and succeeds John Arnsman who will now work on new mechanical developments.

THEORY AND PRACTICE OF GLASS-METAL SEALS

By A. J. MONACK
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PART II

Properties of Metals

Just as in the case of glasses, the thermal expansion coefficients of metals are not necessarily criteria for judging the suitability of sealing to glass. Fortunately, the expansivities of most metals and alloys do not depart from linearity sufficiently to introduce complications. Nevertheless, some alloys do not have straight-line expansions, e.g., Kovar, and the coefficient of expansion should be used with caution.

In Table 5 are found nearly all of the metals and alloys which have been found useful in sealing to glasses or which show promise for such use. A few materials are not included although they are potential sealing metals. Thus, nickel is not listed, although this metal, which normally bubbles badly when sealed to glass, may be used successfully for certain applications if first degassed by firing for 15-30 minutes in air, hydrogen, or vacuum at about 1200° C. Monel metal, which might conceivably be satisfactory for certain types of external seals, is not included. Similarly, certain varieties of stainless steel are excluded. Finally, Table 5 contains no information on metals or alloys which have been plated with copper, nickel, or chromium (other than Dumet and platinum-clad wire), although these combinations have shown at least some indication of successful application. In this connection, silver-plated steel has been sufficiently promising to warrant patent claims[16].

The requirements which in general must be met by metals intended for sealing to glasses may be summarized as follows. 1) The thermal expansion throughout a long temperature range, from below room temperature to above the annealing point of glass, must be uniform. There must be no allotropic transitions accompanied by volume changes in the temperature range in which the glass is too rigid to release strains rapidly. 2) The metal must be stable during the operation of making the seal. The metal must not be soft and must not burn at the sealing temperature. 3) The adhesion to glass must be good. In nearly all cases this means that there must be good adhesion between the metal and its oxide. The oxide formed must not be flaky. 4) Any oxide formed must have a sufficiently low electrical resistance to permit welding or soldering to other metals. 5) The amount of gas given off by the metal must be small. 6) The cost of the metal must be reasonably low.

The detailed information given below, coupled with that of Table 5, indicates the degree of adherence to the above requirements.

1) Platinum. Platinum is the oldest sealing metal. It was used extensively in early tubes and lamps, and is still employed to some extent in laboratory glassworking and in the construction of certain types of scientific equipment. Platinum wire, however, because of its cost, now has no commercial importance in the manufacture of glass-metal seals.

There are certain types of application in which a platinum tube is sealed through soft or hard glass (see Fig. 9). If used with hard glass, it is essential to maintain a ratio of not less than 15:1 between outside diameter and wall thickness of the tube.

It has been found[17] that hardened platinum (the 5 per cent iridium alloy) also gives satisfactory internal tube seals with hard glasses if the above ratio is maintained.

Platinum to be sealed into glass should be thoroughly cleaned. No special heat treatment is required prior to sealing.

When heated to red heat, or higher, and permitted to cool to room temperature platinum does not form a visible oxide coating on its surface. It has generally been assumed that platinum possesses a very stable oxide layer, although Woehler and Frey[18] found that platinum oxides in bulk were unstable at temperatures comparable to those required for glass sealing. Ellefson and Taylor[19] determined that platinum is wet by glass in the absence of oxygen but that a marked increase of wetting occurs in the presence of oxygen. They postulate the formation of a surface oxide or silicate which can be decomposed by reduction of the partial pressure of oxygen gas.

2) Platinum-clad Wire. Because of the high cost of platinum an attempt was made some years ago to retain the advantages of the platinum surface by sheathing a nickel-iron wire with platinum. The core was approximately 48 per cent nickel and 51 per cent iron, and the platinum comprised 30 to 40 per cent of the weight of the entire assembly. The expansion was a match for several soft glasses in reasonably good manner, but the cost was still much higher than was desirable.

3) Dumet. In 1913 B. E. Eldred invented[20] a platinum substitute called Dumet. A large rod of nickel-iron alloy is surrounded by a sleeve of copper. The two are welded or brazed together, then swaged and drawn to the required wire size. The wire is drawn through a bath of molten borax, and the surface of the finished wire consists of a layer of cuprous oxide coated with borax.

The core of this copper-clad wire is an alloy of 42 per cent nickel and 58 per cent iron. The copper sheath constitutes about 25 per cent of the weight of the complete wire.

Since the core alloy may vary in expansion coefficient

16. Miller, H. J. and Spooner, J. M., *U. S Patent*, 2,334,020 (November 9, 1943).
17. Private communication from Edward Wichers.
18. Woehler, L. and Frey, W., *Z. Elektrochem., 15*, 129-42 (1929).
19. Ellefson, B. S. and Taylor, N. W., *J. Am. Ceram. Soc., 21*, 205-13 (1938).
20. U. S. Patent 1,140,136 (May 18, 1915).

TABLE 5
PROPERTIES OF METALS AND ALLOYS

Metal	Commercial form	Expansion coefficient, cm/cm/° C. x 10^7	Thermal conductivity, cal/cm²/sec/° C.	Specific resistance, ohm-cm (20° C.) x 10^6
Platinum	Wire, tube, ribbon, rings, etc.	90.7 (25-100° C.)	0.164	10
Platinum-clad wire Core: Ni 48, Fe 51 Pt: 30-40% of total wt.	Wire to 0.120″ diam.	ca. 90 radial		
Dumet Core: Ni 42, Fe 58 Cu: 20-30% of total wt.	Wire to 0.032″ diam., borax-coated	Radial: 80-100 Axial: 61-65	ca. 0.4	4-6
Platinite Ni 46, Fe 54, C 0.15	Wire to 0.200″ diam.	75	0.038	45
52 Alloy Ni 50, Fe 50 (Carpenter "49")	Wire, rod, ribbon, etc.	95 (20-450° C.)	0.04	43
Chrome iron, 25-30% Cr (Sealmet 1, Allegheny 55, Ascoloy 446, Carpenter "27")	Wire, rod, sheet, ribbon, punched and stamped forms.	108 (20-500° C.)	0.06	72
Fernichrome Ni 30, Fe 37, Co 25, Cr 8	Wire, ring	ca. 92		
Sylvania #4 Ni 42, Fe 52, Cr 6 (Driver-Harris #14, Carpenter "426")	Any wrought form	92 (25-350° C.)	0.032	34
Cold-rolled steel SAE 1010	Wire, sheet, ribbon, etc.	130	0.108	18
Allegheny 4750	Wire, sheet, strip	91 (20-400° C.)	0.037	51
Copper (electrolytic or OFHC)	Sheet, ribbon, thin edge tubes, cups, etc.	178 (25-300° C.)	0.92	1.7
Tungsten	Ground, polished rod	46 (0-500° C.)	0.38	5.5
Molybdenum	Ground, polished rod	55 (25-500° C.)	0.35	5.7
42 Alloy Ni 42, Fe 58 (Carpenter "42", Allegheny 42)	Wire, rod, ribbon, etc.	53 (20-400° C.)	0.038	67
Kovar (Fernico) Ni 28, Co 18, Fe 53	Rod, wire, ribbon, cups, tubing, eyelets, etc.	50 (25-300° C.)	0.046	49
*EMK Fe 71, Mo 10, Co 19, Si 0.8	Rod to 0.5″ diam., ring to 1.25″, wall ca. .040″ Not made U. S. A.	90-95	ca. 0.05	33-37
*Wonico W 80, Ni 13, Co 5	Wire Not made U. S. A.	ca. 55		ca. 13
*Nickel iron (a) vacuum melted (Ni 48, Fe 50, Cr 1, Mn 1); (b) "Ommet" (Ni 48, Fe 52, C less than 0.01)	Wire to 0.200″ diam., Ring and cup to 1.25″ diam. Not made U. S. A.	89	0.038	45
*Chrome nickel Cr 21, Ni 77, Fe 2	Thin-edge ring and cap; thickness at edge 0.002″ Not made U. S. A.	145	0.03	109

*From Espe, W. and Knoll, M., *Werkstoffkunde der Hochvakuumtechnik*, Verlag von Julius Springer, Berlin, 1936.

from 16 to 97 x 10^{-7} as the precentage of nickel increases from 35 to 50 per cent, and since the percentage of copper may vary from a low value to a relatively high one, an infinite series of copper-clad wires is possible. The following formula[21] relates the radial thermal expansion of the finished wire to the composition of the assembly.

$$\frac{p}{s_1} \times 2\beta_2 + \frac{100-p}{s_2} \times 2\beta_1 = \left(\frac{p}{s_1} + \frac{100-p}{s_2}\right) 2\beta, \text{ where}$$

β_1 = coefficient of expansion of the core metal.
β_2 = coefficient of expansion of the sheath.
p = weight of sheath in per cent.
s_1 = density of sheath, g/cm³.
s_2 = density of core.
β = coefficient of radial expansion of Dumet wire.

21. van Liempt, J. A. M., *Recueil trav. chim. Pays-Bas, 52*, 399-402 (1933).

Because of its structure rather unusual properties can be expected in Dumet. If it is assumed that no plastic flow takes place in the copper, then the thermal expansion coefficient should not be equal in the longitudinal (axial) and radial directions. According to Hull and Burger[11] the following equations express the expansions in the two directions:

Axial expansion $= k_1 + 0.209\ (k_2 - k_1)$

Radial expansion $= k_1 + 0.191\ (k_2 - k_1)$,

where k_1 and k_2 are the coefficients of core metal and copper respectively. From these equations the axial expansion is calculated to be about 2 per cent higher than the radial. Experimentally, however, the axial expansion is found to be much lower than that calculated while the radial expansion is considerably higher than the calculated value. Actual coefficients, each the average of four readings, are as follows: axial calculated—8.2×10^{-6}, axial measured—6.5×10^{-6}; radial calculated —8.0×10^{-6}, radial measured—9.2×10^{-6}.

The above differences are readily explained on the basis of stresses which exceed the flow point of the copper, and such stresses exist during heating and cooling because of the considerable difference in expansion between core metal and sheath.

Because of the difference in expansion radially and axially Dumet is not a particularly good match for any glass, and Dumet-glass seals always show considerable strain in the polariscope. In fact, the high tensile stresses set up in the glass make it impossible to use Dumet of large diameter in the commercial production of seals. In lamp manufacture 0.032 in. diameter is the largest Dumet employed. Electron tubes rarely use a diameter over 0.020 in.

The cost of Dumet is relatively high, and in order to reduce the cost of a lead it is customary to make it in the form of a three-piece lead, with a length of nickel or nickel-manganese alloy butt-welded to one end of a short length of Dumet and a length of copper wire butt-welded to the other end. The short length of Dumet forms the seal when embedded in glass. The nickel wire forms the internal connection to the elements of the lamp or tube, and the copper wire is soldered to the pin of the tube base. As a rule both butt welds are sealed into the glass for a short distance.

The coating of Cu_2O on the copper surface of Dumet gives the wires a characteristic reddish color. The borax coating serves to prevent the formation of poorly adherent CuO during the sealing operation and also assists the wetting of the oxide film by the glass. Prolonged heating can cause solution of the entire Cu_2O layer in the glass.

4) Platinite. This alloy of essentially 46 per cent nickel and 54 per cent iron was one of the early substitutes proposed for platinum. The expansion did not match any soft glass closely, and the alloy has been superseded by alloys of other types.

5) 52 Alloy. All members of a series of nickel-iron alloys with nickel contents from 48 to 55 per cent match the expansions of soft glasses reasonably well. Driver-Harris 52 Alloy, containing 50 per cent nickel and 50 per cent iron, which is manufactured commercially for thermostatic uses, has been used to some extent for sealing to glass. Nickel-iron alloys, however, suffer from a serious disadvantage. In all cases oxides of nickel and iron form on the surface when the alloy is heated during the sealing operation. The presence of a large precentage of iron oxide in the surface layer gives a loose, scaly coating which, while wet readily by the glass, does not adhere well to the base metal. No method of pre-oxidizing has been found effective in preventing the formation of an iron-rich oxide layer during processing.

6) Chrome Iron. Chemical analyses of a large number of chrome iron inserts used for seals in metal radio receiving tubes showed the following variations in constituents.

	per cent
Chromium	24 to 28.5
Silicon	0.18 to 0.62
Carbon	0.08 to 0.15
Manganese	0.45 to 0.57
Nickel	0.54 to 0.60
Iron	Balance

In general, the percentage of chromium is 27-28 per cent.

Chrome iron has been used widely in Europe for sealing to lead and lime soft glasses. In this country the chief application has been in the form of inserts for the headers of metal radio tubes, although there is now a tendency to replace this alloy with cold-rolled steel. Chromium-iron alloys with approximately 28 per cent chromium are known variously as Ascoloy 446, Allegheny 55, and Sealmet 1.

The thermal expansion of chrome iron in the range 20-300° C. is approximately 109×10^{-7} per degree C. The expansion curve is somewhat higher than those of the commonly used soft glasses. This is no disadvantage in the case of external seals—is in fact an advantage—but for internal seals the stresses in the glass are higher than is considered desirable. For this reason special glasses, such as Corning 024 in Table 2, have been developed for use in internal seals.

If 28 per cent chrome iron is heated to 1150° C. in air the resulting coating, blackish in color, consists of a mixture of iron and chromium oxides; and it is difficult to make a vacuum-tight seal to glass when this mixed oxide coating is present. It has been found, however, that by heating the alloy in hydrogen carrying water (line hydrogen) or in a partly combusted gas (cracked gas with insufficient oxygen for complete combustion) at a temperature of 1120-1160° C. the chromium is selectively oxidized to form a tough, dense, tightly-adherent surface coating of chromic oxide, Cr_2O_3. The color of the coating on properly preoxidized metal is a moderately dark green. The color varies with the silicon content of the alloy, the darkest color being obtained with the least silicon, and the permissible variations in color are relatively wide. The time required for formation of a suitable oxide coating on chrome iron strips 0.020-0.030 in. thick is 6 to 7 minutes at 1160° C. in line hydrogen.

The surface coating of chromic oxide is very readily wet by glass and is extremely effective in preventing the formation of iron oxides during the sealing operation. Its chief disadvantage is the fact that the electrical resistance is high, and the coating must be removed, usually by sandblasting, before spot welding can be done. Difficulties are encountered in attempting to copper-braze chrome iron to steel in a hydrogen atmosphere because the presence of even a small amount of moisture results in selective oxidation of the chromium.

7) Fernichrome. Hull and Burger[11] announced the discovery of an alloy of 37 per cent iron, 30 per cent nickel, 25 per cent cobalt, and 8 per cent chromium. The expansion curve of this material shows a change of slope which enables it to match the expansions of soft glasses reasonably well. Due to its high cobalt content, however, it is very expensive, and such a quaternary alloy would be extremely difficult to control in manufacture.

8) Sylvania No. 4. Several years ago engineers and metallurgists of the Sylvania Electric Products Corporation carried out an extensive program to develop an alloy for use with Corning's 001 glass. Numerous two-, three-, and four-component alloys were investigated and that composition designated No. 4 was believed to meet more closely than others the conditions which had been set up in advance.

No. 4 alloy is composed of nickel 42 per cent, chromium 6 per cent, silicon 0.12 per cent, manganese 0.29 per cent, carbon 0.04 per cent, and the balance iron. A small amount of a compound-forming element is added to improve adherence of oxide to the base metal.

This alloy is a close match to 001 glass. No thermal critical points occur between—75 and 1000° C. The alloy contains enough chromium to form a protective layer of Cr_2O_3 when pre-oxidized in an atmosphere of wet hydrogen.

Although generally of much smaller size, successful seals have been made with metal rods as large as 0.250 in. in diameter.

By varying the principal constituents of the series of iron-nickel-chromium alloys of which No. 4 is a member coefficients of expansion ranging from 70 to 120 x 10^{-7} per degree Centigrade are obtainable. By a slight variation of nickel and chromium in the No. 4 composition a good match with Corning 012 glass is possible.

9) Driver Harris No. 14 and Carpenter Glass Sealing "426". These alloys are very similar to Sylvania No. 4 and can be used interchangeably. A typical composition is 50.73 per cent iron, 43.13 per cent nickel, 5.47 per cent chromium, 0.32 per cent silicon, 0.28 per cent manganese, and 0.07 per cent carbon. The thermal expansion is slightly higher than that of Sylvania No. 4. No. 14 and "426" are available in any wrought form required.

10) Cold-rolled Steel. Although sporadic attempts, with occasional successful results, were made for many years, it was generally assumed until recently that cold-rolled steel was not a likely material to be used for glass-metal seals. There were no stable glasses with expansion characteristics suitable enough to permit the use of steel in an internal seal. Other types of seals were not vacuum-tight because an excessively thick layer of porous oxide with poor adherence to the base metal always formed during the sealing operation. Attempts were made to borate steel or plate it with copper or nickel to prevent formation of the objectionable oxide, but these methods were uncertain and did not lend themselves to commercial manufacture of seals. The use of a controlled or reducing atmosphere for making the seal likewise was not feasible in large-scale production. A method of silver-plating the steel was developed[16] and this was effective in preventing the formation of an excessively thick oxide of iron although the layer of molten silver seemed to serve also as a flotation medium for removing a portion of the oxide from the metal.

The most direct method, however, is one which makes no attempt to prevent the formation of the normal thickness of oxide but dissolves the excess oxide in the glass[22]. This is done by employing an extremely hot flame which impinges on the outside surface of the metal ring of an external seal for a sufficient length of time (after the glass has been pressed into contact with the inside of the ring) to permit solution in and diffusion into the glass of a portion of the heavy oxide layer.

The thickness of oxide if the supplementary heating is not used is about 0.0002 in. This is produced when the metal is heated to 750° C. and glass at 850° C. is pressed into the ring. If, after this operation, the outside of the ring is raised to 915-1020° C. the oxide thickness decreases to 0.00003 in., while the transported oxide penetrates into the glass (as shown by discoloration) for a distance of 0.0003 in.

SAE 1010 steel is suitable for the above type of external seal. By use of the procedure just described it is possible to dispense with the chrome iron insert formerly thought necessary in the button stem because it was an approximate match for the glass in expansion and to make the entire header of the stem in one piece (see Figures 5.13 and 11b).

During the past few years Corning has produced two glasses, 1990 and 1991, which have expansions that match that of SAE 1010, and these glasses permit the production of internal seals. They have been used rather widely in the manufacture of small single- and multi-terminal headers for soldering or welding into metal envelopes such as transformer cases.

11) Copper. In his classical paper[23] published in 1923, Housekeeper described the series of experiments with copper and glass which culminated in the development of the thin-edge tubular seal which is so often associated with his name. The advent of alloys with expansions close to those of commercial glasses has eliminated the need for flattened copper ribbons except in those rare cases where high thermal and electrical conductivities and low flow point are required in conjunction with ribbon geometry. The disc seal is of more present interest although here again alloys which match the expansions of certain glasses have greatly simplified the problem. The thin-edge tubular seal, however, finds extensive use and will probably continue to do so, particularly as anodes for water- and air-cooled transmitting and other vacuum tubes, because of the high thermal conductivity and extremely low electrical resistance of copper.

For many years it was necessary to use electrolytic copper for drawing and machining anodes. Cuprous oxide is always present in ordinary cast electrolytic copper in varying amounts and distributed as spheroidal inclusions between the crystals. Because of the oxygen contained in these particles gases are formed when electrolytic copper is subjected to reducing conditions at high temperatures, and rupture of the crystal structure, with consequent brittleness occurs. Thus, at temperatures higher than 400° C., hydrogen will diffuse into copper containing cuprous oxide and will reduce the oxide to copper and water vapor. Rupture along

(*Continued on page* 464)

22. Monack, A. J., *U. S. Patent* 2,345,278 (March 28, 1944).
23. Housekeeper, W. G., *J.A.I.E.E., 42,* 954 (1923).

COLORED GLASSES

A Review of Part IV of a Monograph* by W. A. Weyl
Appearing in "The Journal of the Society of Glass Technology," Sheffield, England

PART V

Glass Colored by Metals

The fourth part of Dr. Weyl's monograph on colored glass published in current issues of the *Journal of the British Society of Glass Technology* devotes one hundred pages to glasses colored by the selective absorption of metals in fine subdivision.

A continuous series of color types is said to exist starting from colors caused by ionic constituents of the glass structure and ending with colors caused by the agglomeration of atoms quite detatched from the glass structure.

The continuous character of the series is demonstrated by the existence of transition types such as cadmium sulfide, cobalt iodide or selenium glasses. The latter, which have been discussed in Part III, are closely related to the gold, silver and copper glasses of Part IV. But at high temperatures even ionic constituents of glass may, in part, be reduced to the elemental stage and agglomerate to metallic color centers consisting of several hundred atoms. Gold, silver and copper represent the extreme case of the noble elements.

The discussion of the fundamental principles of the existence of metallic phases in glass comprises the following subjects: (1) Solubility of metals in glass and precipitation of metals from vitreous solutions. (2) Absorption and scattering of light by metallic phases precipitated in glass.

The discussion of the specific metal colors comprises: (1) Gold Ruby. (2) Silver Glasses, Silver Stain. (3) Copper Ruby, Copper Stain.

Solubility of Metals in Glass

Metals are truly soluble in glass; the resulting solution is colorless. Metallophilic groups like lead, tin or bismouth in the arrangement provided by the surrounding glass constituents increase the solubility, particularly at low temperatures. The greater low-temperature solubility affects the growth of the first nuclei of crystallization. The exact number and size of the metallic aggregates thus formed from the solution of metals in glass affects the color of this type of glass to a considerable extent.

Dr. Weyl presents an extensive review of the theory of precipitation and applies the theory to the system metal-glass.

The diffusion of metallic particles through glass is treated as a chemical reaction which is the separation of the diffusing particle from a neighbor in the glass structure with which it was united temporarily. The activation energy of this reaction is included in the diffusion constant which is therefore dependent on the chemical nature of particle and glass, and not merely on apparent dimensions.

The laws of precipitation by Von Weimarn and the Von Smoluchowski equation of coagulation are applied to the process of precipitation and subsequent growth of metals dissolved in glass. For the quantitative treatment the reader must be referred to the original.

For the purpose of this review the complexity of the problem may be illustrated by the listing of some contrasting influences on the growth of gold particles precipitated in glass:

1. Low solubility does not permit the presence of enough gold to obtain the required color intensity.
2. Low solubility favors supersaturation at given concentrations and critical temperatures and, therefore, the desired formation of many small nuclei.
3. High solubility induces the formation of few nuclei and large agglomerates.
4. On reheating, small particles appear to be more soluble, and the organization of properly sized agglomerates is enhanced by recrystallization.
5. At high solubilities recrystallization may lead to oversized agglomerates.
6. At low solubilities, particles may grow by coagulation, instead of recrystallization, i.e., colliding particles adhering to each other grow into large irregular aggregates of gold.
7. Slow cooling enhances the formation of large crystals which withdraw gold from the glass and a ruby color cannot be formed.
8. For certain solubilities slow cooling results in good ruby glasses without recurrence to fast cooling and subsequent reheating.

The solubility of metals in glass is compared in a skillful manner with that of metals in fused salts.

It is shown by the example of organic emulsifiers that the solubility of B in A can be increased by adding C which replaces weak bonds A-B by stronger bonds C-A and C-B. A similar role may be attributed to tin, lead, antimony and bismuth ions which increase the solubility of gold and copper in glass.

Stannous oxide, by its tendency to form in glass both stannic oxide and tin, ties up the glass structure as well as the metal particle. Still stannous ions are stable enough in glass to be available for this purpose and to prevent the excessive growth of metal crystals to which they are selectively attracted.

In this connection Weyl proposes a mechanism to explain the rather mysterious action of tin oxide in the silver mirror formation. The glass surfaces treated with stannous chloride exchange $Na+$ ions with Sn^{++} ions, the residual valencies of which are extended toward silver atoms. The initial precipitation of silver is thus encouraged and further reduction takes place rapidly. At the same time, residual valencies are believed to bridge incompatible glass and metal structures. A full chapter is devoted to the interesting field of silver mirrors.

*For Reviews of Parts I.-III. see Glass Industry, Part I, *6*, p. 262 (1944), Part II, *9*, p. 405 (1944), Part III, *5*, p. 255 (1945), Part IV, *8* p. 375 (1945).

Light Absorption and Scattering by Metals in Glass

Metals differ fundamentally from glass coloring ions by their free electrons which are comparable to the atoms of a gas in their liberty of motion. In ions, electrons tied to positive nuclei oscillate in an alternating field and, at critical frequencies, single electrons jump to a larger orbit absorbing the energy of that frequency corresponding to a color effect. In metals the free electrons form convection currents, contribute little to absorption—much to reflectivity. The thickness of the layer or the particle size affects the relation of reflection and absorption considerably.

Gold particles from 5 to 100 millimicrons show an absorption at 530 mμ which is rather independent of particle size within this range and depends only on the amount of gold present.

The possibility that gold may produce red colors was first established by Faraday who proved that green films of hammered gold were not films of gold in its natural state but under mechanical stress.

Gold particles above 200 mμ do scatter light and cause the predominance of "colloidal" colors; but these colors are the brownish ("livery") colors of "spoiled" gold ruby and not the red colors of "good" ruby. In these brown colors the absorption of gold is superimposed on the scattering effect. The mere scattering effect can only be observed in diluted solutions. Deviations from spherical shape in large particles further modify these complex colorations.

Gold Ruby

Gold ruby, the only red glass of our ancestors, is not only of considerable historical significance, but has retained the interest of the modern scientist. Invented by Kunckel (1630-1705) the gold ruby glass had to be rediscovered in the 19th century. At that time it was believed to be closely related to the Purple of Cassius, a preparation in which metallic gold is precipitated by a mixture of stannous and stannic chloride. However, gold ruby glass can be obtained in the absence of tin.

The theory that metallic gold causes the color of gold ruby (Schubarth 1844) was established by the classical work of Faraday (1857). The puzzling fact that glass contains metals in pure colorless solution was substantiated by many workers in the late nineteenth and early twentieth centuries. A faint purple color may be produced by one of gold in one hundred thousand parts of lead glass; deep gold ruby glasses contain about one part of gold in a thousand parts of glass. Gold is not very soluble in soda lime silica glasses, and the red ruby color is obtainable only in the presence of tin oxide. In tin free glasses the solubility increases with the lead content.

Gold is usually introduced in the form of gold chloride; 1/3 to ¾ parts of gold per 1000 parts of glass was found to be contained in analyzed samples of commercial gold ruby glasses. Gold ruby glass must be melted at high temperatures for long melting periods, cooled fast and then reheated to develop the proper color by "striking."

Rapid cooling produces high supersaturation and the precipitation of a large number of small nuclei. If the molding operation does not permit rapid cooling, the presence of tin oxide in the glass is necessary to prevent too rapid precipitation. In "bad" ruby glasses only a small number of nuclei is formed and the color remains a faint pink in the best case; on reheating the few nuclei grow into larger crystals which impart opacity to the "bad" ruby glass.

For certain gold contents, glasses containing certain amounts of lead and tin, may permit the formation of a sufficient number of nuclei during cooling and the reheating process is unnecessary. In these glasses some gold remains dissolved and unutilized.

Dr. Weyl accounts for the variation of crystals obtained by various reheating procedures and describes eight types and transitions of these types into each other.

Gold ruby has been used mostly in cased ware, where a thin layer of an intensely colored ruby glass covers a bulk consisting of ordinary colorless glass.

Silver

The coloration of glass by silver is caused by the aggregation of elemental silver, in contrast to colors imparted by the usual ionic colorants, and is analogous to formation of gold and copper ruby glasses. The yellow color imparted by silver is dependent upon the size of aggregation; if the particle size approaches the atomic dimensions, the glass is colorless. In the colloidal range, particularly in a base glass of high refractivity, nearly all colors can be observed. If the aggregation leads to large clusters, dirty greens are frequent, however, again a series of various colors of metallic appearance occurs. Under certain conditions the coloring silver combines to highly reflecting surface mirrors. The most frequent yellow color of silver glass is distinguished from the otherwise similar amber colors by the UV transmission. The absorption maximum is above 400 mμ. In a low state of aggregation elemental silver exhibits fluorescence in glass.

The coloration of glass by silver can be accomplished in two ways: (1) Incorporation of silver and its compounds in the batch. (2) Introduction of silver into the rigid colorless glass by surface treatment. The glasses made according to the first procedure may be termed silver glass proper. The second procedure is generally referred to as silver stain. The section on silver in Dr. Weyl's color monograph is divided in two chapters following this classification.

Silver Glasses Proper

The production of glasses by the incorporation of silver in the batch is rarely undertaken. It has been claimed that the method has never been practiced at all. The reluctance of the glassmaker toward preparation of silver glasses has been due to the sensitivity of the glass to thermal fluctuations and other conditions resulting in the formation of cloudy aggregates, and to the lack of characteristic color in the glass.

Silver is incorporated into glass in the form of the silver ion. The source of the silver ions may be oxidized metallic silver or a silver compound. In the glass the silver ions are reduced to atoms by the presence of some reducing agent, such as ferrous oxide. In the absence of a reducing agent, the required electron may be supplied by oxygen from the glass structure, this oxygen being

(*Continued on page* 477)

INVENTIONS AND INVENTORS

A Summary of Recently Issued Patents of Interest to the Glass Industry

Feeding and Forming

Patent No. 2,405,557 is an invention by E. R. Bonnefoy-Cudraz of Courbevoie, France. It shows a machine for making lamp bulbs or other thin blown articles. The title is vested in the Alien Property Custodian and anyone who wishes may obtain a license on the usual terms.

It is stated in the patent that in the manufacture of lamp bulbs from gobs produced by the usual gob feeders, imperfect ware is produced due to the shear mark which is found at each end of the severed gob. The invention overcomes this trouble by delivering the gob to the forming apparatus with its long axis horizontal instead of vertical. The arrangement is such that the bulb or other ware is made from the central part of the gob and both shear marks are in the moil which goes to cullet.

In Fig. 1, a gob V delivered from a commercial glass feeder is received in a chute g which turns the gob into a horizontal position before it is delivered to a cup 110 through an opening 210. Inside the cup and above the gob is a vertically movable head 68 and a short distance below the bottom of the cup is a work table. Closing the orifice is a so-called "obturator head" 58.

Fig. 2 shows the head 68 after it has been lowered to press the gob. It will be seen that the severed ends of the gob are pressed outwardly beneath the bottom edge of the cup as shown in Fig. 3. The head 68 being raised and the obturator head 58 lowered as shown in Fig. 4, leaves the center of the gob free to sag through the opening in the table 51 into the form V^6 shown in Fig. 6. A blow head 41 is then lowered and a blank as shown at V^7 is formed. A mold 25 then closes about the blank and the bulb V^8 is formed. The table 51 is then tilted and a revolving knife severs the moil above the table by some means not described.

The machine is shown as being of the turret type with eight heads. The operating mechanism provided makes the machine fully automatic.

Glass Wool and Fiber

Patent No. 2,405,036 relates to a method and apparatus for making glass fibers and small beads. The patent was assigned to The Linde Air Products Company by James A. Hoffman.

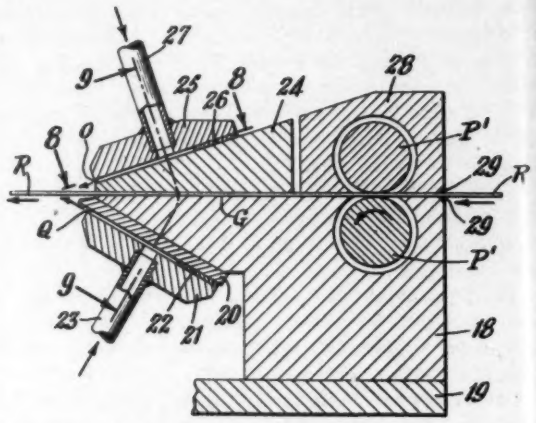
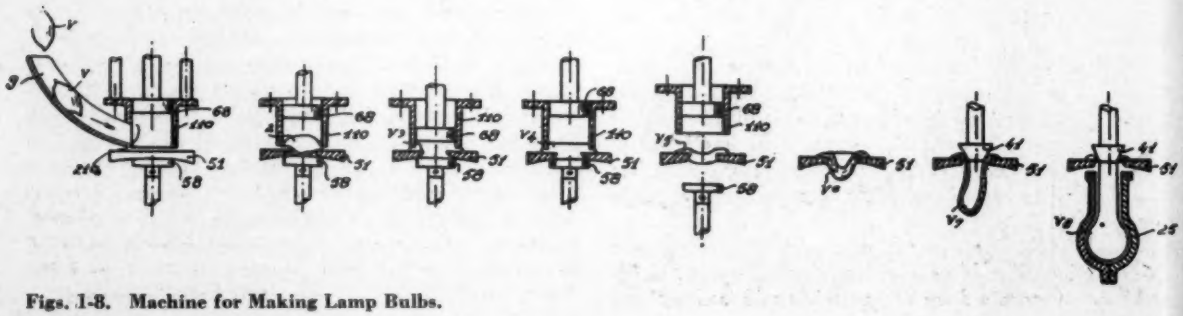


Fig. 9. Method of Making Glass Fibers.

This invention purports to be able to make fibers having a diameter of 0.00012 inch whereas by previous methods diameters smaller than 0.00024 could not be produced. The value of this small fiber is made plain in a patent to Slayter et al, No. 2,234,986, where it is stated that the flexibility of yarn or fabric increases inversely as the cube of the diameter of the fiber. Therefore, the fiber produced by this invention should make a yarn or fabric having more than twice the flexibility of that heretofore manufactured.

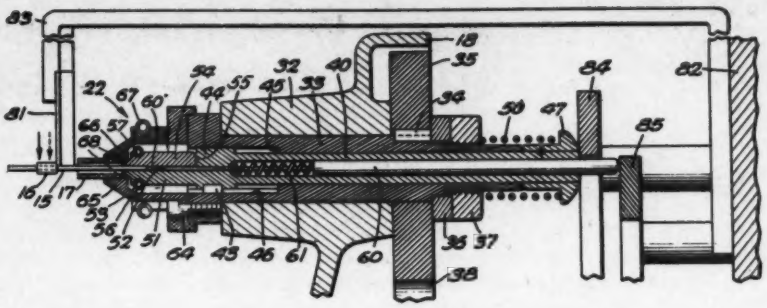
The general construction of a machine for carrying out this method is shown in Fig. 9 in which a glass rod R is advanced by rollers P^1. There may be several of these rods closely spaced to form sort of a ribbon. These rods have a diameter of from 0.001 to 0.005 inch. A nozzle O is formed between a block 24 and a cap 25 through which fuel, such as oxygen and ordinary fuel gas, is discharged from a supply pipe 27. The flame extends across the series of rods R and is directed toward them at an angle of about 15 degrees. Below the rods there is a nozzle Q which discharges air against the rods, also at an angle of about 15 degrees. As shown by the arrows, the air strikes the rods shortly beyond the flame from the upper nozzle O. The relation between the speed of the rolls P^1 and the temperature of the flame and the air pressure from the nozzle Q is such



Figs. 1-8. Machine for Making Lamp Bulbs.

that an extremely fine fiber is formed.

The above operation has been performed with a feeding speed on the glass rod of about 40 feet per minute and an air pressure at the nozzle O of from 75 to 90 pounds per square inch. When the rod speed is reduced to between 5 and 20 feet per minute, a great number of spherical heads will be formed. The heat and air pressure may be varied to assist in the production of beads.



Figs. 10-11. Western Electric Machine for Working on Vacuum Tubes.

Miscellaneous Processes

Patent No. 2,405,504 is a machine for assembling parts of vacuum tubes and it was assigned by the inventors, Juvinall and Stuhlfauth, to Western Electric Company. The object of the patent is to provide an improved apparatus for assembling and attaching glass beads and skirts to lead-in wires of vacuum tubes.

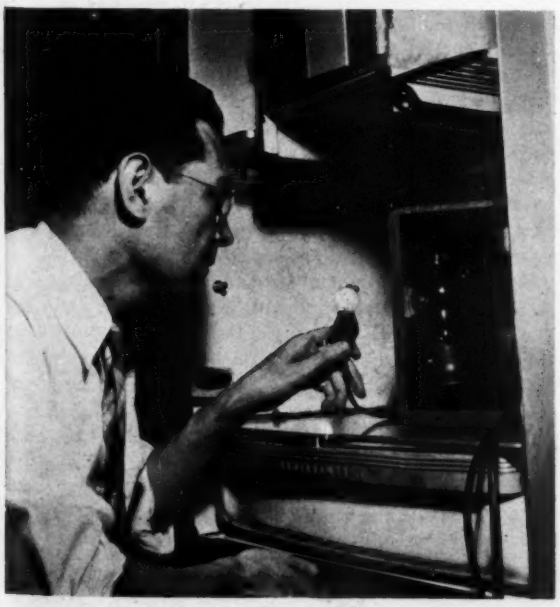
The machine is of the turret type, having eight heads which are intermittently advanced from a loading station to a positioning station and then to fusing stations where the bead is first fused onto the wire and then the skirt is fused onto the bead.

Fig. 10 is a section through a station where the bead 16 has been positioned and fused onto the wire 15 and the skirt 17 is about to be fused to the bead. The wire 15 is held in a chuck 51 and 54 in a position determined by a plunger 60. A second chuck 65 holds the skirt 17. The position of the bead is fixed by a cam plate 81. Cams 84 and 85 are arranged so that after the head leaves the position shown in the figure, the wire 15 with its attached bead 16 is retracted to bring the bead inside of the skirt. At the next station, suitable burners fuse the bead and skirt together and the finished product is then ejected in the form shown in Fig. 11.

WESTINGHOUSE DEVELOPS MIDGET ULTRAVIOLET LAMP

A midget ultraviolet Sterilamp which will improve the food-keeping qualities of home refrigerators has been announced by the Westinghouse Lamp Division.

The new lamp, mounted inside the cabinet, simultaneously emits bacteria-killing rays and produces ozone in the air. In high humidity cabinets where spoilage and mold growth would otherwise soon occur under the higher temperature and humidity conditions maintained to preserve natural flavor and condition of foods, the new Westinghouse development can become an indispensable unit. In lower humidity cabinets, the main problem has been accumulation of food odors. The ozone produced by the Sterilamp diffuses rapidly throughout the entire cabinet purifying the food vapors by breaking down the vapor molecules.



The three and one-half watt miniature Sterilamp operates only when the refrigerator compressor runs and on this basis, at least a year's life for the lamp is assured. The transformer required also consumes but three and one-half watts. The cost of the transformer and the lamp is about half that of the former refrigerator Sterilamp.

A.C.S. GLASS DIVISION MEETING

The dates of September 13 and 14 have been set for the 1946 Autumn Meeting of the Glass Division of the American Ceramic Society. The meeting will be held in Columbus, Ohio.

A tentative program, announced by R. F. Brenner, Program Chairman, includes a business session, inspection of Battelle Memorial Institute and DuPont Color Laboratory and Division luncheon for the morning of September 13. On that afternoon, symposium A on Glass-Metal Seals will be held in the Chemistry Building of Ohio State University and symposium B on Glass Density will be held in the Social-Administration Building of the University. At night, reports will be made on the European glass situation by H. H. Blau and C. J. Uhrmann.

Dr. W. E. S. Turner, who is on a visit to the United States, will address the Division on Saturday morning. This session will be held at the Social-Administration Building of the University. Following luncheon on Saturday, the golf players will compete for the O. Hommel trophy on the Scarlet Course, Ohio State University.

Research Digest

Industrial Use of Radiation Pyrometers Under Non-Blackbody Conditions

In the November, 1945 issue of the *Journal of the Optical Society of America,* T. R. Harrison discusses the principles of non-blackbody radiation and of the application of emittance corrections for various industrial conditions. Besides the commonly treated case of radiation from a non-blackbody in the open, others discussed are radiation from a heated object surrounded by walls at a higher or lower temperature, radiation from an object viewed through flame, smoke and furnace gases, and radiation from glass.

In the discussion on radiation from glass, it was stated that glass reflects, absorbs and transmits light and other radiant energy; its spectral absorptance at any given wave-length equals its spectral emittance at that wave-length. A thin layer of glass lying at a depth beneath the surface will both absorb and emit radiant energy of a given wave-length in direct relation to the spectral absorption efficient $k\lambda$ of the substance. In its transit toward the surface, the radiant energy emitted from such a thin layer is reduced by absorption by the intervening mass. The fraction of the original energy reaching the surface is given by the expression e^{-x} where $x = k\lambda\ t$. Thus, from a layer relatively close to the surface, practically all of the radiant energy arising within the layer and directed toward the surface will reach the surface; from a layer at a depth $t = 0.7/k\lambda$, for which $x = 1$, about 37 per cent reaches the surface, and from a depth giving $x = 4.61$ only about one per cent reaches the surface. Thus, the term e^{-x} determines the relative extents to which the layers at various depths contribute to the entire spectral radiation from the mass and the numerical value of $1/k\lambda$ fixes the actual depths within the glass for which the specified fractions apply.

If it is desired to have a pyrometer to respond as largely as possible to the temperature of layers deep within the mass, it follows that the pyrometer response should be limited, as far as practicable, to those wave-lengths for which $k\lambda$ is relatively small so that correspondingly large values of t are required to give any chosen value of x.

A Pyrex lens about 5mm thick transmits radiant energy in the wave-length band between about 0.3 microns and 2.6 microns though it transmits relatively little radiant energy at longer wave-lengths. A fused silica lens of similar thickness transmits equally well throughout the band transmitted by the Pyrex lens and, in addition, it transmits fairly freely in the wave-length band from 2.6 microns to around 3.8 microns. Most glasses are rather good emitters within the latter band of wave-lengths, though many are poor emitters at wave-lengths below 2.6 microns unless the emitting mass is appropriately thick.

Thus, where it is desirable to measure temperatures at a considerable depth within a large mass of glass, the use of a radiation pyrometer having a Pyrex lens has the advantage that its transmission is limited to those wave-lengths for which usually $k\lambda$ has a small value so that a large fraction of the radiant energy received by the pyrometer arises from appreciable depths within the glass.

In many industrial applications, the mass of glass whose temperature is to be measured is not thick enough to make it completely opaque to radiation of all wave-lengths. In order to obtain pyrometer readings as representative as possible of the true temperature of glass under such conditions, it is preferable to use a pyrometer responsive to the wave-lengths for which the absorption coefficient $k\lambda$ of the specimen is relatively high so that the pyrometer responds largely to radiant energy emitted by layers of glass relatively close to the surface sighted upon. Thus, for such cases, the use of a radiation pyrometer equipped with a fused silica lens is preferable to one having a Pyrex lens. Another advantage of the fused silica lens is that at the relatively low temperature usually involved in glass temperature measurement, a very considerable fraction of total blackbody radiant energy has wave-lengths between 2.6 and 3.8 microns. A good portion of this energy, being passed by the fused silica lens, causes appreciably higher e.m.f. to be developed by the pyrometer.

When the thickness of the specimen is ample for complete opaqueness of all of the wave-lengths affecting the pyrometer, spectral emissivity and total emissivity equal unity minus the reflectance of the material. For most glasses, reflectance equals about 0.04 for such wave-lengths, so that $e\lambda = 0.96$ and $e_t = 0.96$ for masses of most kinds of glass when of ample thickness.

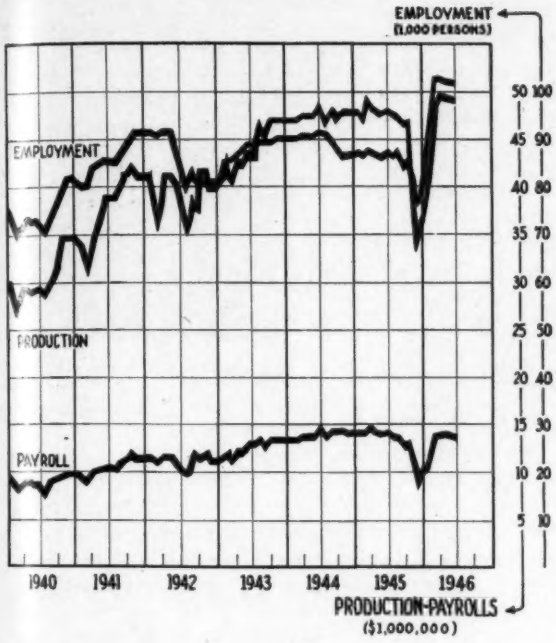
For thinner masses of glass contained in a crucible, a portion of the energy at those wave-lengths for which $k\lambda$ is relatively small will emanate from the walls beyond the glass. For such a case, a composite reading of glass and crucible temperatures is obtained.

When sighting upon glass in the open, such as in a container plant, a radiation pyrometer equipped with a fused silica lens should be employed in preference to one having a Pyrex lens. The instrument should be calibrated under actual plant-operating conditions. As an example, in the measurement of temperature in a glass feeder, a thermocouple is immersed in the glass at a point upon which the radiation pyrometer is sighted, or at a nearby point, and the readings obtained from the thermocouple are used as a basis for calibrating the radiation pyrometer.

Harrison also gives tables and curves for obtaining emittance corrections applicable for a radiation pyrometer equipped with either Pyrex or fused silica lens. The use of an optical pyrometer as a "checking instrument" is also discussed and a table and curves are given for emittance correction where $\lambda = 0.65\mu$. Comparisons are drawn between the readings of the optical pyrometer and radiation pyrometers having the two types of lens, for the condition, $e\lambda = e_t$ (e_λ — spectral emittance and e_t = total emittance). For certain cases, data and precedures are given by means of which emittance corrections are obtainable. For other cases, only the underlying principles are discussed.

CURRENT STATISTICAL POSITION OF GLASS

THE GLASS INDUSTRY'S INDEX



Activity in the glass industry during the month of June showed only a slight decline from the figures reported for the month of May. According to the Production Index, June production was estimated to be $48,800,000. For the month of May, the Index showed an estimated production of $49,000,000. Production during June 1945 was $48,000,000, which is about 1 per cent under June this year. The total estimated production for the 6-month period ending June 1946 is $283,800,000. During the corresponding period last year, production had reached a total of $286,000,000.

Employment and payrolls: Figures on employment and payrolls for June also varied only slightly from those indicated by the Production Index for May. Employment during June was about 101,300 persons. For May, the number of persons employed was 101,500. However, the June figure is about 14 per cent above the 88,400 reported during June 1945.

Payrolls for June dropped from the estimated $13,300,000 reported for May to about $13,200,000. June 1945 payrolls were estimated at the same figure as that reported for June 1946—$13,200,000. Thus far this year, glass manufacturers have paid out about $67,200,000 in salaries. During the corresponding period in 1945, manufacturers paid out an estimated $83,200,000.

Glass container production during July 1946, based on figures released by the Bureau of Census, rose about 6 per cent to 9,604,432 gross. Production during June was reported to be 8,991,276 gross. During July 1945, production was 8,643,174 gross, which is about 11 per cent under production for July this year. Total glass container production during the January-July period of 1946 is 65,789,505 gross as compared with 59,503,784 gross produced during the corresponding months in 1945.

Shipments also showed an increase for the month of July. They rose from 8,874,333 gross shipped during June to 9,232,410 gross. This figure indicates an approximate 4 per cent increase over June. Shipments during July 1945 totalled 8,680,153 gross, which is about 2 per cent under July this year. Total shipments made during the first seven months of 1946 are 65,820,783 gross, as compared with 61,130,720 gross shipped during the same period in 1945.

Stocks on hand at the end of July were 4,089,662

(*Continued on page* 458)

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in gross)

		Production July 1946	*Stocks July* 1946
Foods; Medicinal & Health Supplies; Chemicals, Household, Industrials, Toiletries & Cosmetics	Narrow Neck	3,312,823	1,855,390
	Wide Mouth	3,176,899	1,071,792
Dairy Products		292,414	121,283
Beverages, Returnable		648,160	324,279
Beverages, Non-returnable		.....	.....
Beer, Returnable		318,416	92,370
Beer, Non-returnable		60,536	16,409
Liquors		839,958	167,144
Wines		390,124	55,482
Home Canning, Packers' Tumblers		565,102	385,513
Total		9,604,432	4,089,662

GLASS CONTAINER SHIPMENTS

(All figures in gross)

	July, 1946
Narrow Neck Containers	
Foods	961,561
Medicinal & Health Supplies	1,019,524
Chemical, Household, Industrials	559,770
Beverages, Returnable	595,237
Beverages, Non-returnable	.....
Beer, Returnable	314,598
Beer, Non-returnable	59,267
Liquors	777,823
Wines	367,896
Toiletries & Cosmetics	541,632
Sub-Total (Narrow)	5,197,308
Wide Mouth Containers	
Foods	2,522,733
Dairy Products	283,570
Medicinal & Health Supplies	254,622
Chemical, Household, Industrials	116,264
Toiletries & Cosmetics	159,518
Home Canning, Packers' Tumblers	436,583
Sub-Total (Wide)	3,803,290
Total Domestic	9,000,598
Export Shipments	231,812
Total Shipments	9,232,410

PEMCO ADDS TO RESEARCH AND DEVELOPMENT STAFF

Announcement has been made by the Pemco Corporation of the appointment of Major Henry H. Thomas to its Research and Development staff.

Immediately after his graduation in 1941 from North Carolina State University with a B.S. in Ceramic Engineering, Major Thomas joined the U. S. Army Ordnance Corps. He served overseas for 23 months and visited many of the foreign pottery manufacturers throughout Italy, England and Sweden gaining much valuable information to aid him in his work with Pemco.

WYANDOTTE NAMES MANAGER PACIFIC DIVISION

The appointment of Charles O. Chestnut as General Manager of the newly organized Pacific Division of Wyandotte Chemicals Corporation was recently announced by the company. The new Pacific Division will direct manufacturing and distributing activities in the Pacific States of the products of both the J. B. Ford and Michigan Alkali Divisions of Wyandotte and of Natural Soda Products Company. The Division will also handle the new Wyandotte organic specialties and fine chemicals.

In addition to his appointment as General Manager of the new Division, Mr. Chestnut was also elected President of the Natural Soda Products Company to replace Stanley Pedder, retired. Prior to joining Wyandotte, Mr. Chestnut was Vice President and General Manager of McCord Corporation.

O-I MAKES KEY APPOINTMENTS

Owen-Illinois Glass Company has recently announced the appointment of Kenneth C. White as Sales Promotion Manager of the Glass Container Division. Mr. White, formerly General Sales Manager of the Libbey Glass Division, succeeds Howard A. Trumbull who has resigned to enter business for himself.

Mr. White joined Owens-Illinois in 1935 and was made Manager of the San Francisco branch in 1941. He directed an O-I development of processing fruits in glass on a continuous operating basis on the Pacific Coast. He was transferred to Toledo in 1944 as General Sales Manager of Libbey.

The appointment of William M. Beckler as Manager of Table Glassware sales of the Libbey Division was also announced by the company. Mr. Beckler joined the Libbey Division twenty years ago, later becoming Manager of Libbey's Chicago branch. He was transferred to Toledo in 1940 and became Sales Manager of Libbey's Institutional Division. He was then made Assistant General Sales Manager of Libbey.

• The Pennsylvania Salt Manufacturing Company has announced the purchase of the Kentucky Babb Fluorspar mine near Salem, Kentucky. The company recently completed underground explorations of the Kentucky Babb mine, but is now producing from it.

A. E. BADGER JOINS L-O-F RESEARCH STAFF

The appointment of Dr. Alfred E. Badger to the research staff of Libbey-Owens-Ford Glass Company has been recently announced. Dr. Badger will work with Dr. R. K. Day in the detailed supervision of laboratory and field research.

Graduating with a Bachelor of Science degree from Case School of Applied Science, Dr. Badger received a Master of Science degree in chemistry and a Doctor of Philosophy degree in engineering from the University of Illinois. He also studied at the Kaiser-Wilhelm Institut fur Silikatforschung in Germany.

Dr. Badger has been associated with the General Electric Company and, until his present appointment, has been associated with the University of Illinois where he has been Research Associate Professor of Ceramic Engineering and consultant to many glass manufacturing firms.

Dr. Badger has published more than 60 papers on the theory and practice of glass technology and in silicate chemistry. His publications have dealt with fundamental properties of glass, formation of minerals, X-ray studies, test methods and a broad field of effect of chemical composition on physical properties.

BOOKLET ON MELLON INSTITUTE WAR ACTIVITIES

Mellon Institute has recently published a booklet containing subjects used in a series of radio talks describing the essential research programs headed by the speakers and giving summaries of the results.

The subjects contained in the booklet and the speakers are "Research in the Conquest of Malaria" by R. Stuart Tipson, Mellon Institute; "Research Improves Resistors for Radio and Radar" by Edward E. Marbaker, The O. Hommel Company; "The Triumph of Synthetic Rubber" by Charles F. Winans, Koppers Company, Inc.; "Maintaining Workers' Health in the Industries" by John F. McMahon, Mellon Institute; "Science Solves Pressing Textile Problems" by Jules Labarthe, Jr., Mellon Institute; and "Good Strokes in Life Preserver Research" by E. Gray King, Mellon Institute.

These subjects were selected mainly because of their public interest to illustrate a few of the Institute's activities and contributions during World War II.

• The Little Giant Glass factory in ten months' operation has completed the manufacture of 100,000 minnow traps and has started installation of new equipment for other manufacturing. The company has signed a contract for large scale production of six-gallon bottles to be used by distilleries in advertising their products. Soft drink bottlers also are purchasing this type glass container. About 2,000 lamp chimneys per day have been manufactured in recent weeks.

NEW EQUIPMENT AND SUPPLIES

HOMMEL DEVELOPS PORCELANITE

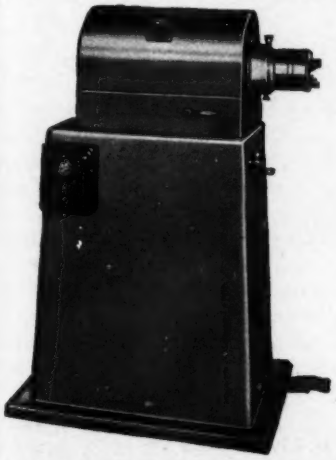
The O. Hommel Company, Pittsburgh, Pa., has announced the development of a new semi-glazed, porcelain-like finish porcelanite for protecting cold rolled and cast iron burning racks, burning tools, iron and glass furnace interiors, saggers, lehrs, decorating kilns and ladle-linings.

This semi-glaze finish prevents burning racks and tools of cast iron and steel from scaling. Stainless steel tools are cleaned easier after being coated with porcelanite and the life of paint is extended.

Porcelanite forms a semi-glaze finish over brick and clay in furnaces, sealing all crevices. The corrosive action of gases, flue dust and slag is materially reduced and the furnace retains its heat in a satisfactory manner. The finish prevents discoloration of molten-glass, chinaware and porcelain enamels by the iron oxide present. It can be sprayed or applied with a brush. It air sets and the oven can be fired immediately.

IMPROVED SPEED LATHE

Schauer Machine Company, 2116 Reading Road, Cincinnati, Ohio, is manufacturing a variable-speed lathe which, it is stated, provides a new and advanced method for cleaning, lapping



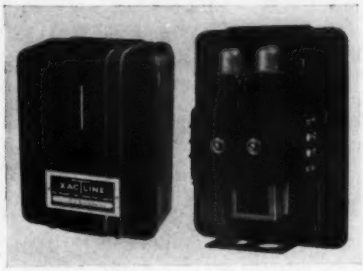
and polishing dies, molds, plungers, etc.

For precision lapping and polishing, the piece to be polished is automatically centered. Speed of the operation is at the option of the operator. Variable speeds from a minimum of 25 RPM to a maximum of 275 RPM, or of 400 RPM to 4800 RPM, are available. Variations of spindle speeds are accomplished by movement of a variable pitch pulley, controlled by a conveniently located balcrank.

The motor is coupled to the work spindle through a twin-disc clutch assembly and variable speed drive. Other features are a continuously operating motor, single foot-pedal control of clutch and brake and disc-type brake for extremely fast stopping of the spindle.

NEW TYPE "STRAIGHT LINE" TEMPERATURE CONTROL UNIT

Claud S. Gordon Company, 3000 S. Wallace Street, Chicago 16, Illinois, has announced a new Xactline temperature control providing variation as low as 1/5 of a degree F. and power



"on-off" cycles as short as three seconds.

Xactline accomplishes this without the use of cams, motors, bearings, shafts, gears or other rotating mechanical parts. It is inexpensive and can be used on all types of electric furnaces, ovens, injection molding machines, etc., employing conventional millivoltmeter and potentiometer type controlling pyrometers or gas-fired equipment employing solenoid-controlled or motor operated valves. It is housed in a cast aluminum case 8¼″ high x 6¼″ wide and 3″ deep and is designed for surface mounting installation.

LIGHT BELT GRINDER ATTACHMENT

The Porter-Cable Machine Company, Syracuse, New York, has added a light, narrow belt grinder attachment to its line of abrasive belt grinders.

Suitable for light burring and grinding operations, Type N-2 is said to combine the versatility of platen grinding with the economy and speed of contact grinding, and is especially useful for light grinding of flats, arcs, angles, gear burring, weld grinding, cleaning-up operations, etc.

The attachment is furnished without motor and is quickly aligned and attached to the familiar bench type wheel grinder to which a resilient contact roll has been fitted. The complete unit assembly stands 27″ high with a width of 2½″. A 6″ x 7″ T-shape base is drilled with 3 holes for convenient mounting to bench or work table. Platen size for flat grinding is 2″ x 4″. Resilient contact rolls 2″ x 6″ or 1″ x 6″ can be furnished. Using an endless abrasive belt 2″ x 48″, the attachment can be used either in the vertical, horizontal or any angle between the 90 degrees.

CATALOGUES RECEIVED

Union Pacific Railroad, Omaha, Nebraska, has issued a booklet giving a brief history of the railroad's progress through the years.

The hardships endured during the days of the first railroads, the trouble the first construction crews had with the Indians, and the improvements made down through the years are all described in this booklet. Photographs show the first railroad ties and those of the present day, together with pictures of the first car models and the streamline trains in use today. A map of the United States indicates the route of the Union Pacific line.

The Chas. Taylor Sons Company, Dept. D, Cincinnati, Ohio, has issued a bulletin, No. 201, relative to Taylor zircon refractories for high temperature service and applications.

The bulletin is the first complete outline written on zircon refractories and their application to various industries. It is well illustrated throughout and gives tables and descriptions of zircon refractories, crucibles, fire clay brick hearths, zircon hearths and zircon air-setting cement.

Frazier-Simplex, Inc., Washington, Pa., has recently published a 20-page booklet describing Simplex lehrs. The booklet is well illustrated with photographs and two-color heat diagrams showing the method of heat application in the lehrs.

The various lehrs described and illustrated in the booklet are semi-muffle, full-muffle and electric annealing lehrs, decorating lehrs, decorating equipment, drying ovens, decorating machines and normalizing ovens.

Wheelco Instruments Company, 847 W. Harrison Street, Chicago 7, Illinois, has announced Bulletin D602-A which describes the company's complete line of portable pyrometers.

The bulletin illustrates the Model 2863 portable pyrometer kit and gives full information pertaining to the new extension type lance pyrometer. Specifications for the proper selection of extension holders, adapters and thermocouple tips are also listed in chart form.

Meehanite Metal Corporation, 800 Pershing Square Building, New Rochelle, New York, has just published a four-page bulletin, No. 23, entitled "Meehanite—The Metal for Permanent Molds".

The bulletin describes and illustrates Meehanite permanent molds used in the production of glass, metals, plastics and rubber.

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CURRENT STATISTICS . . .

(*Continued from page* 455)

gross. At the end of June, 3,728,888 gross were on hand and, at the end of July 1945, stocks on hand were 3,943,156 gross.

Plate glass production for July 1946 rose about 12 per cent over June 1946, according to the Hughes Statistical Bureau. Production for July was 18,408,556 sq. ft. and for June it was 16,315,599 sq. ft. Plate glass production for July 1945 was considerably under July this year. The figure reported was 8,480,795 sq. ft. Total plate glass production for the first seven months of 1946 totals 109,598,633 sq. ft. in comparison with 56,961,922 sq. ft. produced during the same period in 1945.

Automatic tumbler production for the month of July rose close to 62 per cent from June. Production was 11,966,205 dozens as compared with 7,388,960 dozens in June. Automatic tumbler production during July 1945 was reported to be 5,338,304 dozens. Shipments, however, fell off approximately 5 per cent for the month and were 5,984,036 dozens. For June, shipments were 6,347,476 dozens, and for July 1945, they were 5,630,495 dozens. Stocks on hand at the end of July 1945 were 10,609,145 dozens. At the end of June, inventories were 4,919,876 dozens.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware for the month of July 1946 dropped about 7 per cent to 3,553,057 dozens. During June, sales were reported to be 3,846,905 dozens. July 1945 sales were 2,475,500 dozens. Total sales during the 12-month period ending July 1946 were 43,865,835 dozens.

STAFF CHANGES AT BALL BROTHERS

Ball Brothers Company has announced the appointment of three new assistant sales managers. They are Earl A. Sheffield H. S. Miller and Marvin Babcock, Sr. These men will serve in this capacity for the Fruit Jar and Domestic Products Division of the company.

Mr. Babcock has been associated with Ball Brothers for the past 33 years and will continue to devote his time to assisting the Sales Manager in the company's general offices in Muncie.

Mr. Miller and Mr. Sheffield will work in the field. They have been connected with the company for 25 and 24 years, respectively.

OPTICAL SOCIETY ANNOUNCES ANNUAL MEETING

The Optical Society of America will hold its thirty-first Annual Meeting at the Hotel Pennsylvania, New York City, on October 3, 4 and 5. It is indicated that there will be a large number of contributed papers on a variety of subjects, including spectroscopy, spectrographic analysis, vision, color and color reproduction, the use of photo-tubes in photometry, etc.

The annual dinner will be featured by an address on the subject of Aerial Photography by Colonel George W. Goddard.

OWENS-CORNING NAMES DIRECTOR OF PURCHASING

George E. Gregory was named to the newly created position of Director of Purchasing, according to a recent announcement made by the Owens-Corning Fiberglas Corporation. Mr. Gregory will assume these new duties in addition to his present position as Vice President in charge of commercial development.

Mr. Gregory joined the company in 1938 as General Sales Manager. This was the year in which the company was established. Formerly, he had been Manager of the Fiber Products Sales Division of Corning Glass Works. He was named Director of Fiberglas sales in 1942 and became Vice President in 1943.

As well as directing purchasing and contract relationships, Mr. Gregory will administer the firm's Traffic Department covering shipping activities at the Fiberglas factories in Ohio, Pennsylvania, Rhode Island and at the plant now under construction in Kansas City, Kansas.

The appointment of Arthur R. Smith, Jr., as General Purchasing Agent to succeed R. R. Bastian, resigned, was also made known. Mr. Smith joined the company in 1944.

PITTSBURGH PLATE APPOINTS SAFETY DIRECTOR

It has recently been announced by Pittsburgh Plate Glass Company that Thomas R. Donoghue has been appointed Safety Director. Mr. Donoghue will have complete jurisdiction over the industrial safety program in all the plants operated by the company.

Upon joining the company in 1920, Mr. Donoghue first served as safety and mining engineer at the Crystal City, Missouri, glass plant. In 1925, he became safety engineer at the firm's Creighton, Pa., plant and continued in that capacity for a 15-year period. He then served at the Columbia Chemical Division's Barberton, Ohio, plant.

When Columbia Chemical Division was requested by the government's Defense Plant Corporation to build and operate a plant at Natrium, West Virginia, Mr. Donoghue was appointed Personnel Director of the new unit. He remained in that post until his present appointment.

PITTSBURGH SECTION ANNOUNCES FALL MEETING

The Pittsburgh Section of the American Ceramic Society has announced September 20 as the date for its opening Fall meeting. The meeting will be held at the East Liverpool, Ohio, Country Club.

Arthur Wells, well-known barbecue chef, will sponsor a demonstration of the use of the Infra-red ox-roasting equipment. The program will include plant visits, golf, dinner and entertainment.

KUAN-HAN SUN JOINS WESTINGHOUSE

Kuan-Han Sun, formerly with the Kodak Research Laboratories, has recently joined the staff of the Westinghouse Research Laboratories.

Dr. Sun was graduated from the National University of Chekiang at Hangchow, China, in 1936 with a B.S. degree. In the same year, he won a fellowship by a nation-wide competitive examination from the National Tsing-Huda University for advanced study in America.

Upon coming to America in 1937, Dr. Sun enrolled in the University of Pittsburgh and received his M.S. degree in 1938 and his Ph.D. in 1940. He was a postdoctorate fellow in the University of Pittsburgh from 1940-1942 and compiled the "Data on Chemicals for Ceramic Use" for the National Research Council. Dr. Sun joined the Kodak Research Laboratories in 1942. He is President of the American Chapter of the Chinese Ceramic Society.

$25,000,000 EXPANSION ANNOUNCED BY WYANDOTTE

An expansion program of $25,000,000 which is expected to increase the corporation's sales by more than 30 per cent by 1948, has been announced by Wyandotte Chemicals Corporation. Plans include the entering of Wyandotte into the organic chemicals field on a large commercial scale after producing inorganic chemicals and cleaning materials for over fifty years.

Although a decision to enter the field of glycols and related compounds was made in 1944, it was not until this year that wartime restrictions permitted the construction of the necessary buildings and installation of new equipment. Principal product of the glycol unit will be a substantially pure grade mixture of ethylene and propylene glycols.

Other products of the glycol unit will include chloroethers, polyglycols, ethylene and propylene dichlorides and solvent napthas. The plant will utilize a process not now in commercial operation and protected by patents owned by Wyandotte Chemicals Corporation. Principal raw materials will be petroleum, chlorine and lime.

The expansion phase of the new construction program includes increased capacity for almost all of the company's alkali products. Soda ash capacity will be stepped up by 15 per cent. Chlorine expansion will exceed the additional requirements for captive use and will provide adequate supplies for increased needs of Wyandotte customers in the paper, chemical, textile and water purification industries. Capacity for precipitated calcium carbonate will be increased from two to five units, each of the three new units having 50 per cent more capacity than the original units built.

The calcium carbonate expansion is expected to be completed by January 1, 1947, while the other inorganic plants will not be finished until January, 1948. The additional capacity for these inorganic products will approximate 600 tons per day.

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JAMES ASHLEY NAMED L-O-F PUBLIC RELATIONS DIRECTOR

Libbey-Owens-Ford Glass Company has named James M. Ashley as Director of Public Relations to replace the late North A. Wright. Mr. Ashley has been in charge of the company's Washington, D. C., office for the past few years.

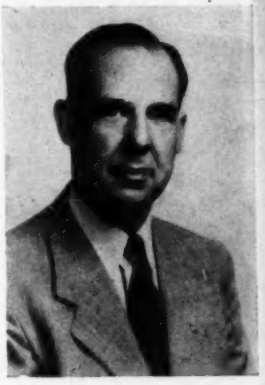
In 1934, Mr. Ashley joined L-O-F at the East Broadway safety glass plant. He was later transferred to the Minneapolis office and then to Chicago. In 1938, he established a sales office for the company in Washington, D. C.

During the war, Mr. Ashley maintained Army and Navy contacts in connection with L-O-F's war manufacturing program for military equipment, working closely with government designers and military officials in solving many emergency problems.

Mr. Ashley will have general supervision of the company's advertising, sales promotion, publicity and department of design operations.

NORTH CAROLINA COLLEGE APPOINTS DR. KRIEGEL

The North Carolina State College has appointed Dr. William Wurth Kriegel as Professor and head of the Department of Ceramic Engineering at the University. He succeeds Dr. A. F. Greaves-Walker, retired.



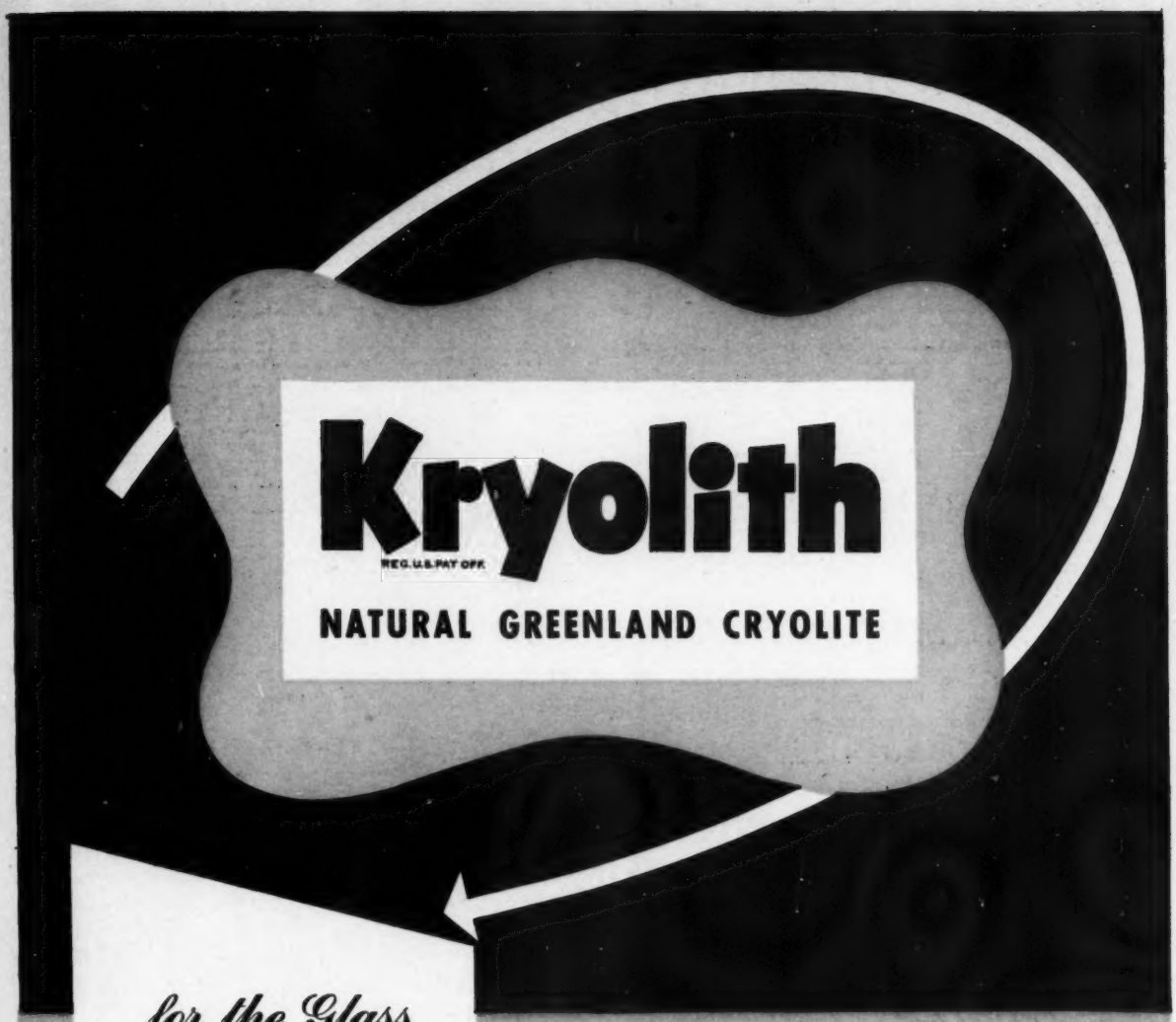
Dr. Kriegel received a Bachelor of Science degree in Civil Engineering and a Bachelor of Science in Ceramic Engineering at the University of Washington. In 1936, he was granted a Master of Science degree at Montana School of Mines. He later was awarded the degree of Doctor of Engineering by the Technische Hochschule in Germany.

Beginning his teaching in 1934, Dr. Kriegel remained with the Montana School of Mines until 1939. He then became instructor of Ceramic Engineering at North Carolina State College and was Associate Professor when he was called to active duty in the Army in 1941. He returned to the College in 1945.

L-O-F APPOINTMENT

Announcement has been made of the appointment of G. M. Sollenberger to the post of District Industrial Sales Manager at the Libbey-Owens-Ford Glass Company's Cincinnati office.

Mr. Sollenberger was formerly with the company's Cleveland office as Industrial Manager. He is succeeded there by George Neukom, Jr.



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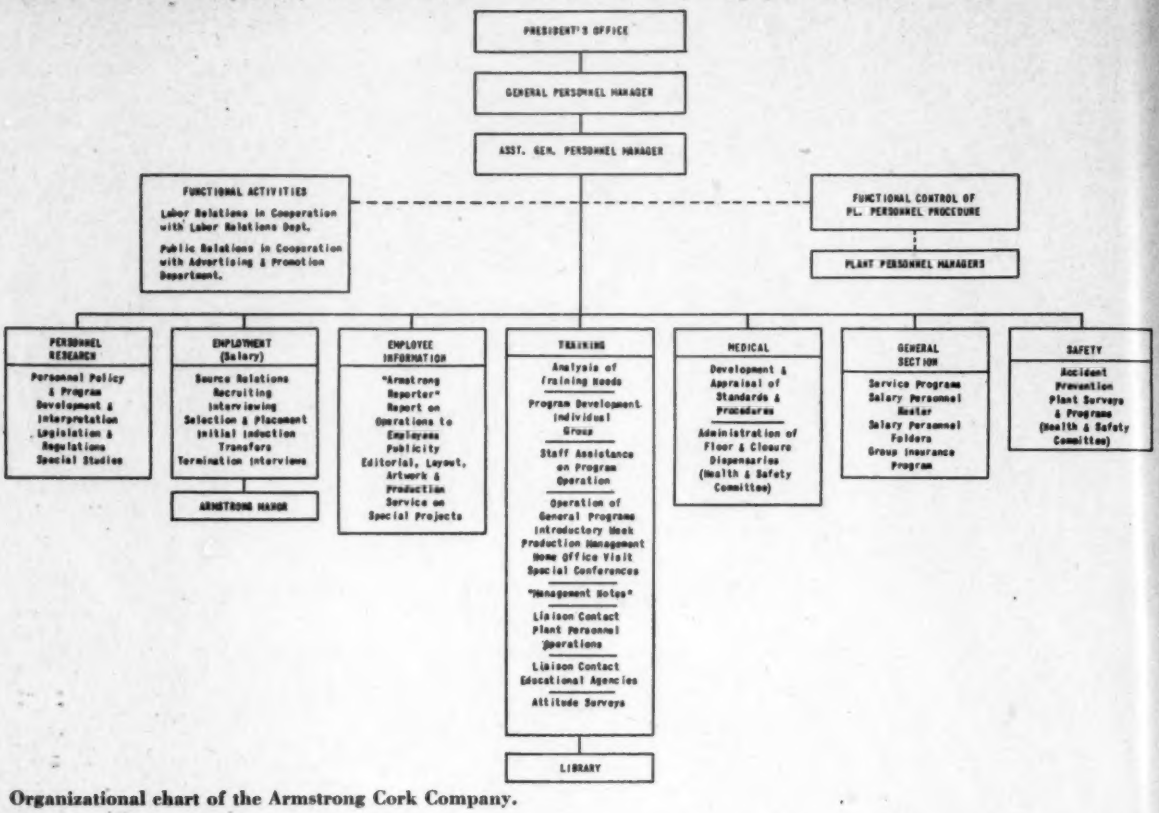
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GENERAL SECTION
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SAFETY
Accident Prevention Plant Surveys & Programs (Health & Safety Committee)

Organizational chart of the Armstrong Cork Company.

analysis and plan with his supervisor and establishes a schedule for the plan of development to be followed. This plan does not contain the undesirable features of the so-called "Merit Rating Plans," but rather emphasizes constructive analysis and development. Experience has proved that, in addition, it assists the superior to determine better the methods of approach in dealing with his individual supervisors for maximum personal guidance.

5. The Individual Training Plans Procedure. Training is, in last analysis, an integral part of supervision. Unfortunately, to many people the term "training" signified only formal group programs and classroom work and ignores the informal, day-by-day opportunities for individual learning. The Individual Training Plans procedure recognizes that both formal and informal training are necessary and sets up, in definite schedule form, the course to be followed by each supervisor. Training methods included in this schedule are: 1) Special coaching by superior; 2) Special coaching by staff representative; 3) Brief assignment in another department; 4) Enrollment in evening courses; 5) Visits to other plants and companies; 6) Assignment to trade and technical association meetings; 7) Long-term plan of position assignments; 8) Participation in group training projects; and 9) Utilization of presently available training material.

6. The Personnel Folder. Industry has long recognized the necessity and value of maintaining accurate records of sales, cost, equipment, materials, and other tangible factors of the business. Not always has such emphasis been placed on the value of records dealing with the human element of the organization. But today these records serve as an inventory of the people available for placement on the basis of need, and as a basis for planning individual development. Armstrong's Personnel Folders present an orderly history of the employment of each individual and all changes affecting him. They aid in the selection of new supervisors, and contain records of the training and qualifications of old ones.

Armstrong believes that supervisors, carefully selected and trained under this varied program, provide one of the best possible methods of keeping employees abreast of company policies and practices.

Additional information is carried to employees by "The Armstrong Reporter," a company news magazine that is mailed each month to the home of every worker. This magazine contains a wide variety of articles and pictures of activities in all the Armstrong plants and, in addition, serves as a medium for publicizing company matters that are of interest to employees. For "spot" or "flash" news between issues of the magazine, notices are posted prominently on bulletin boards.

For programs as important and as far-reaching as Armstrong's Group Insurance, Retirement, and Income Security plans, special booklets setting forth their provisions are given to all employees. In this way the booklets are available for study during leisure time and can be kept for future reference.

These three programs—Group Insurance, Retirement, and Income Security—are similar to those carried on by most progressive corporations but bear further mention here because of their importance in Armstrong's basic ten-point personnel policy.

(Continued on page 474)

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(*Continued from page* 449)

grain boundaries results because hydrogen diffuses through copper faster than water vapor escapes by diffusion, and sufficient pressure to rupture the metal is built up. Foreign oxides in copper are also reduced by hydrogen.

It is evident that serious difficulty can be encountered with a thin-edge seal if cuprous oxide inclusions or holes at the grain boundaries occur at or above the line where the glass of the seal ends (see Fig. 5.6a, b, c). In this region the thickness of the metal is not great and small holes can result in leakage through the metal.

Because of the danger of embrittlement and leakage it is necessary to anneal electrolytic copper in vacuum.

In order to overcome the above objectionable features oxygen-free and high conductivity (OFHC) copper was developed. This metal is made by melting high-purity electrolytic cathode copper under carefully controlled conditions of atmosphere and temperature and casting the metal under these same conditions. Microscopic examination reveals no cuprous oxide between crystals, and no other oxides are present in sufficient quantity to be harmful. Its freedom from oxygen makes it possible to silver-solder, braze, or weld OFHC copper without danger of hydrogen embrittlement.

For use as anodes for power tubes, phosphorus, zinc, and managanese in OHFC copper should not exceed 0.0003 per cent of each impurity.

In the heat treatment of thin-edge copper seals, such as annealing, it is well to bear in mind that grain size in copper increases rapidly at 600° C., the rate of growth increasing ten-fold between 600° and 700° C. for OHFC copper. Grain size of the magnitude of 0.004 in. can in many instances mean that the metal above the seal is merely one crystal thick. Crystal boundaries are then extremely vulnerable surfaces.

Formation of cupric and cuprous oxides when copper is heated have an important bearing on the use of copper as a seal metal. As an upper limit a temperature of 1065° C. can be set since this is the melting point of the eutectic mixture of copper with 3.5 per cent Cu_2O. For oxidation in air at atmospheric pressure the temperature should not fall below 1026° C. if the formation of CuO is to be prevented. Even when the rate of cooling is slow, however, only a thin film of CuO is formed if the temperature has been above 1026°. If the oxidation is conducted below 1026° in air at atmospheric pressure a layer of CuO is first formed. Cu_2O is subsequently formed next to the copper if the temperature is not too low. If the temperature is too low a black film of CuO which will not adhere to the copper is formed.

In actual practice the recommended procedure is to heat the copper to about 1030-1040° C. Without letting the copper cool, the glass is heated to the working temperature, and glass and metal are brought together. Heating is continued for about 15 seconds to permit complete wetting of the copper by glass and probably slight solution of copper oxide in the glass. Careful flame annealing is then performed.

The method of sealing is essentially the same with both soft and hard glasses. The temperature of soaking after the glass has been brought in contact with the copper is somewhat higher in the case of hard glass.

From the discussion above it is obvious that the entire procedure is planned to prevent the formation of loose, flaky CuO and to insure the presence of Cu_2O which adheres well to the metal. The color of the completed seal is an indication of success in this respect, the color being a medium to dark red in the case of soft glass and a bright opaque yellow-red or orange-red in the case of hard glass.

12) Tungsten. Tungsten has been the most important metal used for internal seals with hard glasses. Its specific resistance (slightly lower than that of molybdenum) is lower than that of any other metal or alloy used for internal seals—lower in fact than that of any other sealing metal for any type of seal except copper. This fact, among others, accounts for its suitability in the manufacture of electron tubes which operate at high power. Because of the heat generated during the operation of such tubes, as well as the high degassing temperatures for the metal parts within the tube, it is essential that hard glass be used, and tungsten and molybdenum are the only two matching metals that are generally suitable for internal seals. In addition, the tube elements to be carried by the lead wires are usually rather large and heavy, and the rigidity of tungsten and molybdenum is important in this respect.

Tungsten for seals is obtained in the form of ground and polished rods. Freedom from longitudinal internal fissures and surface cracks and scoring is extremely important since the surface tension of glass is not sufficiently low to fill the latter and there is no certain way of preventing leakage through the former. Various diameters are used, usually 0.080 in. or less although rods as large as 0.200 in. have been sealed successfully into glass.

Because of its cost tungsten is often reclaimed from glass stems and re-used. Oxidized tungsten can be cleaned by immersion in a bath of molten sodium nitrite at 300° C. or electrolytically in a 10 per cent solution of sodium hydroxide with an alternating current of 12 volts. Even new tungsten rods should be cleaned before pre-oxidation if there is any question concerning the condition of the surface.

In the usual process for sealing tungsten through glass a tungsten rod of the required dimensions is oxidized by heating to a yellowish red or an incipient white heat, a short length of glass tubing with inside diameter slightly greater than the diameter of the rod is slipped around the tungsten, and the glass is fused to the metal to form what is called a beaded lead. Such a lead seals readily into a glass flare or bulb.

If a vacuum tube using tungsten leads is examined an orange-red color (occasionally blue or black) is seen to surround the tungsten where it is sealed through the glass. This color evidently has its origin in the oxide layer formed on the tungsten by heating. Since the tungsten, if properly oxidized, is bluish-black in color some change has taken place in the operation of fusing glass to the lead. Little, if any, light on the subject can be found in the literature.

The oxides of tungsten have generally been given[24] as WO_3, W_2O_5, and WO_2. Smithells and Rooksby[25] obtained X-ray diffraction patterns for these oxides.

(*Continued on page* 466)

24. Mellor, J. W., *A Comprehensive Treatise on Inorganic and Theoretical Chemistry*, Vol. XI, Longmans, Green, 1931, p. 689.
25. Smithells, C. J. and Rooksby, H. P., *J. Chem Soc.*, 1927, p. 1882.

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(*Continued from page* 464)

Chaudron[26] determined the equilibrium conditions between hydrogen, water, tungsten, and its oxides as given above; and van Liempt[27] deduced from Chaudron's results the equilibrium constants. Tarjan[28], however, stated that no oxide with the composition W_2O_5 exists, that the true composition is W_4O_{11}, and that further reduction of W_4O_{11} leads without intermediate step to WO_2 and finally to tungsten. Ebert and Flasch[29] confirmed the existence of W_4O_{11} and described a new compound W_8O_{23}.

It is generally agreed that the colors of the oxides and mixtures of the oxides are as shown in the following table:

Color	*Composition*
Yellow	WO_3
Greenish blue	$WO_3 + W_2O_5$ (W_4O_{11}?)
Dark blue or bluish violet	W_2O_5 (W_4O_{11}?)
Purple brown	$WO_2 + W_2O_5$ (W_4O_{11}?)
Chocolate brown	WO_2
Brownish black	$WO_2 + W$
Grayish black	W
Gray	W
Metallic gray	W

While many of these colors are found in glass-tungsten seals under varying conditions of manufacture and thermal and electrical treatments no definite clue is given concerning the composition of the intermediate layer. An X-ray investigation[30] established the following:

(a) If a tungsten rod is heavily oxidized the oxide layer consists of approximately 80 per cent WO_3 and 20 per cent W_2O_5. After glass has been sealed to the wire, with the usual time of heating and no heat soaking after the glass has wet the metal, the color of the seal is bluish-black and the oxide layer consists of W_2O_5 with traces of WO_2.

(b) If a tungsten rod is oxidized in the normal manner the oxide layer is thinner than in the previous case and consists chiefly of W_2O_5 with a small amount of WO_3. After the seal is made the color is an orange-red and the oxide layer consists of WO_2 with a possible trace of W_2O_5.

(c) There is a discrepancy between the chocolate brown color of WO_2 in powder form and the orange-red color of a glass-tungsten seal which X-ray diffraction shows to be essentially WO_2. The orange-red may be due to a trace of W_2O_5, to a difference in particle size, to colloidal suspension of oxide in glass, to a solid solution of oxides, or possibly to formation of a tungsten bronze with alkali from the glass[31].

13) Molybdenum. Molybdenum has many characteristics which are greatly similar to those of tungsten. The thermal expansion is somewhat higher and, as a rule, this requires the use of glasses other than those which are employed with tungsten. The specific resistance is very slightly higher than that of tungsten.

While it has been sealed into glass for support leads in many types of tubes, molybdenum has not been used widely for "lead-through" purposes, notwithstanding the fact that it is cheaper than tungsten and is much less susceptible to cracks and fibrous defects. The chief objection for many years has been the strong tendency of molybdenum to over-oxidize during sealing or beading. This disadvantage, however, can be overcome by careful technique and the metal is being more widely employed for seals than formerly.

Because of its tendency to form a thick, non-adherent, semi-liquid oxide molybdenum should always be beaded by fusing a close-fitting glass to the metal. This beaded lead can then be sealed into a glass stem or bulb without difficulty. The non-adherent nature of the oxide makes it desirable to choose a glass with higher expansion than that of molybdenum so that the glass exerts a radially compressive force on the metal when at room temperature.

As in the case of tungsten, molybdenum is in Group VI of the Periodic Table and may have a variety of valences. Again as in the case of tungsten, some of the oxides reported in the literature require valences that are not whole numbers (e.g., Mo_3O_8, valence = 5.33). This indicates either a mixture of oxides or a complex crystal in which the metal atom takes part in more than one type of grouping in the crystal (e.g., the spinel structure of Fe_3O_4). The colors of certain of the oxides of molybdenum are reported as follows:

Color	*Oxide*
Violet	Mo_2O_3
Brownish-black	MoO_2
Blue	Mo_3O_8
Dark violet	Mo_2O_5
Yellowish white	MoO_3

Mo_4O_{11} and Mo_5O_{12} are said to exist. The valences in these cases would be 5.5 and 4.8, respectively.

A heavily oxidized molybdenum rod shows a coating of yellowish white MoO_3 over dark violet Mo_2O_5. Intense heat drives off oxide in the form of a heavy vapor. The action is apparently one of true sublimation. If oxidation is done between 600 and 800° C. the oxide film is not excessively thick. A normally oxidized lead is a dark violet color, and on beading such a lead the color changes to brown, often with a suggestion of violet.

Molybdenum rods are purchased in ground and polished form. For degassing and cleaning the surface of volatile and combustible contamination the metal can be fired at 1065° C. for 45 minutes in line hydrogen.

Molybdenum leads for electron tubes vary widely in diameter, from fine wires to heavy rods. Diameters of $\frac{3}{8}$ in. are not uncommon, and even larger sizes have been used on occasion.

Cleaning methods employed with tungsten are generally satisfactory for molybdenum.

14) 42 Alloy and Glass Sealing "42". Driver-Harris 42 Alloy is another member of the nickel-iron family of alloys. The thermal expansion matches that of several of the hard glasses, but use of this material is subject to the limitations mentioned in the discussion of 52 Alloy.

42 Alloy is nearly always employed as the core metal in the manufacture of Dumet.

Carpenter Glass Sealing "42" is very similar to 42

(*Continued on page* 468)

26. Chaudron, G., *Comptes rendus*, **170**, 1056-8 (1920).
27. van Liempt, J. A. M., *Z. anorg. Chem.*, **120**, 267-76 (1922); **126**, 183-4 (1923).
28. Tarjan, E., *Naturwiss.*, **19**, 166-7 (1931).
29. Ebert, F. and Flasch, H., *Z. anorg. Chem.*, **217**, 95-104 (1934).
30. Unpublished data by A. J. Monack, F. E. Haworth and E. E. Beeton.
31. Smithells, C. J., *Tungsten: A Treatise on Its Metallurgy, Properties, and Applications*, Chapman and Hall, Ltd., London, 1926, pp. 38-39.

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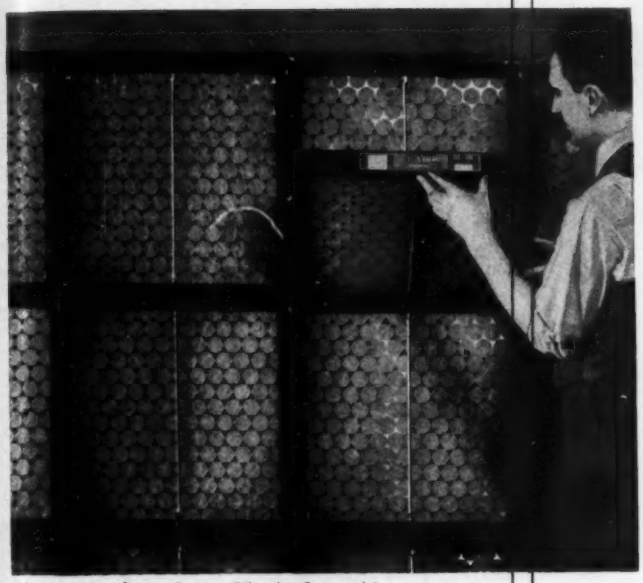

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(*Continued from page* 466)

Alloy and may be used interchangeably. Both alloys have served most successfully in the form of thin-edge cups. An example of this type of application is found on "sealed beam" automobile headlights. The thin edge is embedded in the glass to form an edge seal (see Table 1) rather than true tubular seal, although the latter have been made.

15) Kovar (Fernico). In 1930 a report was published by Scott[32] on the results of his detailed investigation of the thermal expansion characteristics of alloys in the iron-nickel-cobalt family, and further information was reported in 1931 by Masumoto[33]. It was found that certain alloys in this family had inflection points in their expansion curves and that inflection points could be chosen to match closely those of certain hard glasses. These inflection temperatures are Curie points or temperatures at which the alloys lose their ferro-magnetism. The shape of the expansion curve below and above the inflection is almost exactly that of several hard glasses. It is evident that such an alloy is extremely important in the technology of glass-metal seals.

The names Kovar and Fernico have been applied interchangeably to an alloy of 53% iron, 28% nickel, and 18% cobalt which has proved to be most suitable for seals with glass. Hull, Burger, and Navias[34], however, have reserved the name Fernico for an alloy of 54% iron, 31% nickel, and 15% cobalt, which is said to be still more stable than the previously mentioned composition. Kovar is more readily procurable in many forms and is used in the great majority of applications. Chemical analyses of samples of Kovar show the following:

Iron	52.46 to 53.30%
Nickel	27.91 to 28.54
Cobalt	18.14 to 18.55
Manganese	0.19 to 0.29
Silicon	0.06 to 0.30
Calcium	0.13 to 0.23
Magnesium	0.001 to 0.005

The preferred composition is:

Iron	52.9-53.4%
Nickel	28.7-29.2
Cobalt	17.3-17.8
Carbon, max.	0.06
Manganese, max.	0.50
Silicon, max.	0.20

British Kovar-type alloys have been discussed by Redston and Stanworth[35].

Kovar is polymorphic and its low thermal expansion is characteristic only of its gamma or face-centered cubic form. The alpha or body-centered form has an extremely high expansion. Fortunately, the gamma-alpha transformation occurs below −80° C. The gamma-alpha transformation can be produced by cold working, such as rolling and drawing and filing. The gamma phase can be restored by annealing for 5 minutes at 900-1200° C. Annealing is generally combined with degassing and cleaning by firing for 1 to 4 hours at 900-1100° C. in line hydrogen.

Kovar is usually oxidized at a temperature of about 650° C. In many cases no pre-oxidation is performed, the heat of sealing being more than ample. Overheating of the metal results in the formation of a thick black oxide which adheres well to glass and metal but is porous.

The specific oxides formed when Kovar is heated have not been studied. It is reasonable to assume, however, that cobalt oxide is a major constituent in cases of heavy oxide. Nickel oxide probably forms part of the oxide layer, possibly most of it in a properly made seal, and it is not likely that iron oxide is high in percentage as a rule. The thick, porous layer of an over-oxidized lead may contain much higher percentages of iron, although the rich black color is indicative of CoO.

Correct oxidation results in a seal having a mouse-gray or brownish appearance, the color depending upon the glass used, time of heating, and temperature of sealing. In some cases it is necessary to bead or coat the metal with glass prior to sealing in order to preserve the proper oxide condition.

Oxidized Kovar may be cleaned electrolytically in a solution of sodium chloride containing 10-15% hydrochloric acid. An A.C. current of 12 volts with a current density of 10 amperes per square inch is recommended.

Kovar may be electroplated, tin-dipped, soldered, welded, and brazed. Kovar parts are produced in a great variety of shapes by machining, drawing, punching, etc., and these parts are used in the manufacture of nearly every type of seal listed in Table 1. In some instances it is now the practice to braze Kovar to copper anodes for power tubes in order to eliminate the thin-edge seal.

16) Electroplated Metals. If a glass-metal seal is not required to hold vacuum or pressure it is possible to obtain good, mechanically strong seals with electroplated metals. Expansion relationships between the glass and the base metal are of course not altered by the plating. Plating is useful in those instances where poorly adherent oxide forms on the unplated base metal. For example, copper- or nickel-plated cold-rolled steel, 52 Alloy, or 42 Alloy make mechanically strong seals if done properly. Chromium plating has been used.

There have been many cases in which electroplated metals formed good hermetic seals but the practical difficulties involved have been a serious bar to extended commercial application. The chief problem is not one of firm glass adherence to the plated coating but one of leakage between plating and base metal. The field has never been thoroughly and systematically investigated, and there are undoubted advantages which justify more experimentation.

Plated coatings which have been tried sporadically are platinum, copper, nickel, chromium, and silver. The last-named has a tendency to melt and gather as globules on the base metal, thus permitting formation of undesirable base-metal oxide.

Mechanism of Sealing

The operations involved in making a glass-metal seal are simple enough and well understood. Glass and metal

(*Continued on page* 470)

32. Scott, H., *Trans. A. I. M. E., Inst. of Metals Div.*, pp. 506-38 (1930).
33. Masumoto, H., *Sci. Rep. Tohoku Imp. Univ.*, **20**, 101 (1931).
34. Hull, A. W., Burger, E. E. and Navias, L., *J. Appl. Physics* **12**, 698-707 (1941).
35. Redston, G. D. and Stanworth, J. E., *J. Sci. Instruments*, **23**, 53-7 (1946).

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By F. G. Schwalbe
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GLASS-METAL SEALS . . .
(*Continued from page* 468)

are brought into contact, sometimes by gravity but usually by means of an applied force, at a temperature which is high enough for the glass to be fluid. In general, the temperature of the metal must equal or exceed that of the glass in order to form a satisfactory hermetic seal. In all likelihood the only significance here is the fact that the glass is chilled by the metal if the temperature of the latter is below that of the glass. It can be set down as an essential condition that the glass must be "hot enough" to wet the metal. Once that statement is made it is necessary to enter a speculative field if the discussion is to continue.

"Hot enough" means many things: low viscosity, low surface tension, greatly increased thermal agitation, chemical bonds that approach the weak liquid bonds, increased spacing between ions, an increased number of free ions due to rupture of bonds, many ruptured bonds, and numerous other chemico-physical facts. The explanation of wetting of metals by glass probably comprises several of the above.

The subject is complicated by the fact that superficially and internally a glass at 1000° C. is not the same as a glass at room temperature. Wetting occurs at elevated temperature but we are concerned with adherence at room temperature. We can only conclude that a set of conditions which causes or permits wetting at high temperature persists in some fashion at room temperature.

It has often been taken for granted that the presence of an oxide coating on a metal is essential for wetting of that metal by glass. It has further been assumed that the presence of an intermediate oxide layer between metal and glass is necessary to obtain glass to metal adherence. Ellefson and Taylor[19] found that gold and platinum were wet by molten silicates in the absence of oxygen and without evidence of oxide coatings on the metals. According to Housekeeper[23] a seal to copper can be made without oxide on the metal. Hull and Burger[11] express the opinion that glass might adhere to clean metal. Hull, Burger, and Navias[34] measured the strength of bond of Fernico-glass seals in which the oxide had been completely dissolved in the glass by prolonged heating, and the results showed unquestionable good bonding between metal and glass. Dumet seals may be heated until the cuprous oxide dissolves completely and leakage need not result. Tungsten seals need not leak when the oxide is completely dissolved by heating. There is ample evidence, therefore, that the presence of oxide is not a requisite condition for a successful seal.

Another usually accepted opinion is one which postulates a "graded seal" between metal and glass, which gradually merge into one another through the medium of an oxide layer which is soluble in both metal and glass. Since seals can be made to clean metals it is obvious that the "graded seal" theory is not a necessary explanation. It is true that most oxides are readily soluble in glass. It is true that metal oxides dissolve in metals. By proper manipulation of time, temperature, partial pressure of oxygen, etc., it is possible to obtain a "graded seal" of the mutually soluble type. Nevertheless, it can be said with certainty that in many seals there is little solution of oxide in the glass. Whatever solution or diffusion occurs, the depth of penetration into the glass is probably not much greater than ionic dimensions. This is not surprising. Glass at its working temperature is far from a fluid liquid. The surface tension and viscosity are high; the time of contact at high temperature is short. Careful microscopic examination of seals fails to disclose evidence of a definite oxide-glass zone. In the glass itself there is little or no discoloration caused by solution or suspension of metal ions. The demarcation between oxide and glass is often very sharp and seems to be a true discontinuity. If the oxide-metal junction is investigated a sharp boundary is found in many cases. Thus, a tungsten-glass seal breaks at the oxide-metal interface with a clean fracture. The copper of a thin-edge seal can be pulled or rolled away from the seal so that all oxide is left as an adherent coating on the glass while the exposed copper surface is essentially oxide-free. Hence, while there is no doubt some penetration of oxide into the glass and possibly some penetration or solution of oxide into the metal, the conception of a "graded seal" consisting of *metal* : *oxide in metal* : *oxide* : *oxide in glass* : *glass* is probably too ideal.

The matter of the presence or absence of metal oxides in seals is somewhat academic since formation of oxides is a natural result of heating metals in order to seal them to glass, and prevention of oxidation is costly and troublesome. In fact, the chief problem in sealing technique is one of preventing the formation of excessively thick oxide. It is quite possible that if oxides did not always form normally on heating (with the probable exception of the noble metals) there would be no speculation on the role of oxides in glass-metal seals.

It can be said with certainty, however, that glass will wet an oxidized metal surface more readily than it will a clean metal surface. This may be considered solution of oxide in the glass but it is actually more correct to call it penetration.

Because of the very definite indications that glasses will wet and bond to both a clean metal surface and an oxidized metal surface it is necessary to assume that two types of action take place in sealing (unless it be agreed that even a clean metal surface is covered by an invisible oxide coating). On the other hand, if it is assumed that a metal oxide is merely a metal ion combined with an oxygen ion, while a metal consists purely of metal ions, then the explanation of adherence need involve only a metal ion.

According to the Drude-Lorentz theory a metal is to be regarded as an assemblage of positive ions immersed in a gas of free electrons. The attraction between the positive ions and the electron glass gives the structure its coherence. Sommerfeld's modification in terms of the exclusion principle and its extension by Bloch to take into account the wave nature of the electrons do not alter the conception of metal ions. It is thus quite possible to seek a single explanation to cover the wetting of both metals and metal oxides by glass.

Hull and Burger[11] express the opinion that an important factor in the wetting of clean metals is congruence between the metal lattice and the molecular dimensions of the glass. Apparently the structure of the metal lattice is not critical since copper, nickel, alpha cobalt, and gamma iron all have the cubic close-packed structure, while chromium, molybdenum, tungsten, beta cobalt, and alpha and beta iron have either the hexagonal

(*Continued on page* 476)

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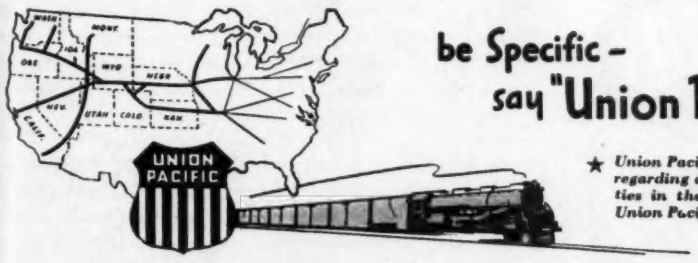

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CHAS. TAYLOR SONS MAKES APPOINTMENTS

Chas. Taylor Sons Company has announced the appointment of Edwin K. Pryor as exclusive sales representative for the company in the states of California, Washington, Oregon, Arizona, Utah and Nevada.

Edwin K. Pryor

A graduate of Ohio State University, Mr. Pryor majored in metallurgical engineering. He spent five years in the Michigan-Ohio and West Virginia area as sales engineer for Chas. Taylor Sons and has recently completed one year of special work on the staff of Battelle Memorial Institute.

Mr. Pryor will devote his time to the development and application of P. B. Sillimanite and Taylor Zircon Super-Refractories among industrial plants in the West.

At the same time, the company made known the addition of W. H. Corban, ceramic engineer, to its sales staff.

Mr. Corban is also a graduate of Ohio State University. He spent five years with the U. S. Army, Corps of Engineers, and received his honorable discharge earlier this year.

FORTER-TEICHMANN AWARDED CONTRACT

Forter-Teichmann International, foreign sales outlet for Forter-Teichmann Co., has been awarded a contract for complete engineering, furnishing and placing in operation plants for the Syrian Glass and Porcelain Industries of Damascus, Syria.

Over one million dollars is involved in the program for the production of window glass, rolled sheet glass, bottles and other glass products.

Forter-Teichmann International handles all of the foreign business of Forter-Teichmann Company.

PENNSALT MAKES STAFF CHANGES

Pennsylvania Salt Manufacturing Company has announced the appointment of Frederick C. Abbott, formerly Manager of the New Products Division, as Assistant Production Manager in the Manufacturing Department.

Named to succeed Mr. Abbott is Hugh Richard Bishop, recently released from the U. S. Army Air Forces. Martin E. Johnson has been transferred from the Market Research Department to the New Products Division.

Mr. Abbott joined Pennsalt in 1943 and was in the Market Research Department before becoming Manager of the New Products Division. He was formerly associated with Phosphate Mining Company, Ozark Chemical Company and the Texaco Salt Company.

• Formation of a new company to serve Sweden and Finland has been announced by Bausch & Lomb Optical Company. Jointly owned by the optical firm and Aga-Baltic Ab, well-known Swedish corporation, the new concern will be known as Aga-Bausch & Lomb Ab. With headquarters located in Stockholm, Sweden, it will serve as a distributor of Bausch & Lomb's entire line of scientific optical and ophthalmic instruments, equipment and eyewear.

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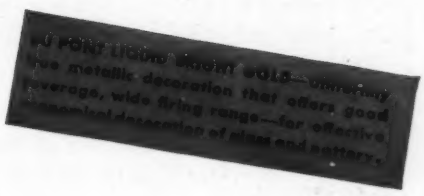

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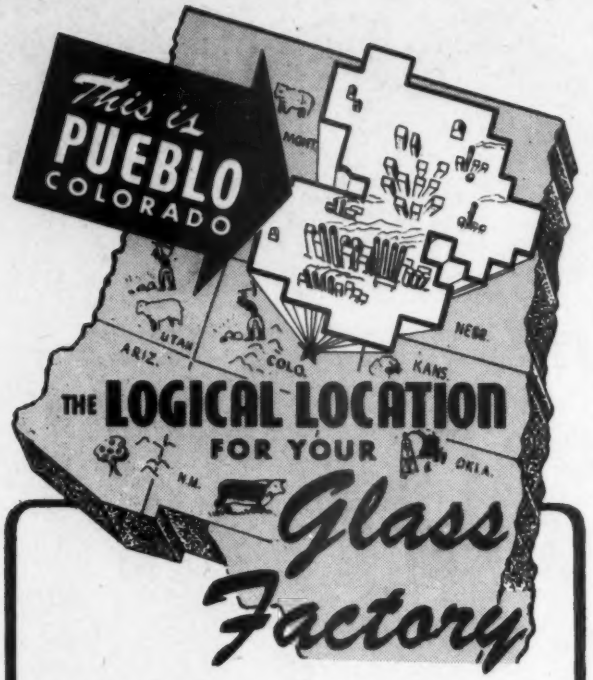

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ARMSTRONG'S PERSONNEL PROGRAM . . .

(*Continued from page* 462)

The Group Insurance Program, which covers life, health, and total and permanent disability, is paid for by the employee and the company on a 50-50 basis. Dividends received from the Insurance Company are distributed to all members of the plan. In the more than 15 years that the program has been in effect, each member has had returned to him approximately 30 per cent of his premiums.

The General Retirement Program, which supplements Government Social Security benefits, provides a liberal income following retirement. This Program consists of three separate parts, two of which are paid for entirely by the company so that an employee participates in a large share of the benefits without making any contributions of his own. However, employees wishing to receive maximum benefits can make small monthly payments, in which event the company adds an additional amount. Overall, the company's contribution to the insured portion alone is approximately 2⅓ times that of the employee.

The Income Security Program is carried entirely at the company's expense and provides unemployment benefits during the period of waiting until state payments begin, a thrift plan facilitating the job of carrying individual savings accounts, and a prepaid wage plan whereby an employee with five or more years of service, who is laid off through no fault of his own, can receive 60 per cent of full income for the balance of the year.

Another prominent feature of Armstrong's Personnel Program is an actively administered suggestion system under which employees are paid for usable ideas that contribute to improved manufacturing methods or products. As an example of the awards that are sometimes paid under this system, one employee at the Millville plant recently received $1,600 for a single suggestion.

In addition, the Personnel Program incorporates a large number of "those little things that mean so much to the individual." "Open House" at the various plants enables the workers to serve as hosts and show their friends and relations just what they do; development of athletic and social activities helps to increase personal friendship and cooperation; presentation of service emblems periodically highlights the unusually large proportion of employees who have been associated with the company for many years; and a lending library, clean locker rooms, and good cafeteria facilities help provide better relationships between the company and its employees.

JESSOP STEEL NAMES BRANCH MANAGER

A recent announcement made by the Jessop Steel Company has made known the appointment of T. F. De Normandie as Branch Manager of the company's Buffalo, New York, office. His office will be in the Liberty Bank Building.

Mr. De Normandie has been associated with Jessop for the past ten years. He has served in the production and sales departments and the sheet and plate division. During the latter part of the war, he was in charge of light armor plate production and sales.

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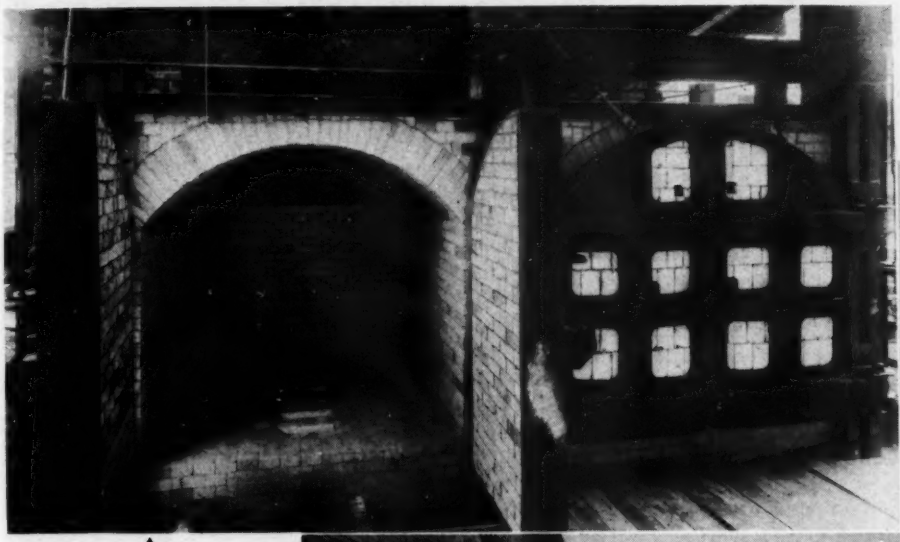

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(*Continued from page* 470)

close-packed or the cubic body-centered structure. When the atomic radii (taken as half the distance of closest approach, without regard to the state of coordination) are considered the following values result: chromium—1.25, iron—1.24, cobalt—1.25, nickel—1.24, copper—1.28, molybdenum—1.36, tungsten—1.36, platinum—1.38. There is good agreement here in some respects but the significance is not clear. It is noticeable, however, that all of these ions have smaller radii than ions of sodium, potassium, calcium, magnesium, and lead which are already present in the spaces in the glass network.

If the oxide theory is assumed valid the explanation is simplified because the metal oxide atoms then contribute oxygens to the glass network, thus increasing the number of single-bonded oxygens which can hold cations in the holes of the network. The action then becomes similar to that which occurs when PbO, for instance, is added to a silica glass. When the seal has cooled to room temperature metal ions are present in the network of the glass surface. This of course is over-simplification because no mechanism is suggested to explain the transition from ionic bonding on one side to metallic bonding on the other. The transition, however, need not be more difficult to explain than the method by which a metal oxide adheres to a metal.

Other explanations are also plausible. King[36] has pointed out the presence of dendritic iron at the interface of enamel and steel. Weyl[37] summarized various mechanisms to explain adherence to glass, among which are formation of an oxide film and entrance of ions into the glass. Spencer-Strong and King[38] found that presence of iron oxide was not necessary for enamel adherence. Perhaps significance should be attached to the contention of Hull, Burger, and Navias[34] that lead is produced at the interface of a lead glass-iron seal (42 Alloy or iron) through reduction of lead oxide by ferrous metals. There is of course no lead oxide as such in glass, only lead ions, and reduction would involve a transfer of two electrons from some source to each of the lead ions to in order to convert these to atoms. The mechanism is difficult to visualize. No other investigators have reported the formation of lead in such cases and confirming evidence is desirable.

In summary, just as no satisfactory theory has yet been advanced to explain enamel adherence to metal no explanation of adherence in glass-metal seals is more than speculative. It is unfortunate that systematic investigations, starting with simple glasses, utilizing existing knowledge of chemical physics, and employing the full arsenal of modern scientific equipment, have not yet been undertaken. Reliance has been placed almost entirely upon empirical knowledge of enamelling and sealing procedures. This situation will undoubtedly show improvement in the near future.

Since oxide is present in all commercial seals, whether essential or not, it is necessary in some cases to keep the oxide thickness to a low value. Usually, when metals oxidize too heavily during the sealing operation, it is possible to exercise good control over the oxide by means of a process called "beading". Beading is merely a pre-coating of metal with glass. If the metal part is a round rod or wire a close-fitting length of glass tubing is slipped over the wire, which is rotating horizontally about its axis, after pre-oxidation to give the required oxide thickness, and fused by means of sharp fires. The fusing is started at one end of the tubing and the fires are advanced along the length as the glass makes contact with the metal. In this way entrapment of bubbles is almost entirely avoided.

The result of the above process is a metal rod on which a glass bead has been fused to cover part of the length of the rod. The diameter and length of the glass bead may vary within wide limits.

Beading may be performed in another manner, by the use of powdered glass (80-100 mesh), and in this sense the term "beading" has been extended to cover pre-coating of any metal shape. The metal is heated to a temperature above the softening point of the glass, powdered glass is permitted to fall upon the hot surface in a fine stream, and the adherent glass is then heated sufficiently to flow over the surface of the metal. If this method is used with hard glasses there is danger of over-oxidation because of the higher temperatures required. This may be prevented by first coating the pre-oxidized part with a thin layer of molten borax or of low-melting glass. An alternative method is to heat the metal part in a gas flame which carries methyl or ethyl borate, thus depositing a layer of B_2O_3 on the metal. Gas may be borized by passing over alcohol containing boric acid.

In addition to its primary function of preventing the formation of excessive oxide, beading in most instances facilitates the making of a seal. It is much simpler to fuse a beaded lead into a hole in a glass bulb than it would be to seal an unbeaded wire into a hole. All things considered, glass adheres to glass more readily than it adheres to metal. In making a stem with hard glasses by forming the glass against tungsten or molybdenum leads between parallel jaws it is difficult with unbeaded leads to avoid capillaries or fine leakage paths along the sides of the wires that do not receive direct pressure. This defect is not likely to exist with beaded leads.

In certain instances metal rods or wires sealed through glass are subjected to bending stresses of considerable magnitude. Beaded leads contribute more rigidity to the structure.

In some types of tubes, such as metal vapor lamps, seals which are subject to temperatures of 200-300° C. or higher on the air side have a tendency to leak in service. Long beads which extend along the leads to a point where the temperature is lower are efficacious[39] in preventing leakage.

Beading is rarely used with soft glasses since borax coating on Dumet wire serves somewhat the purposes. Thin-edge tubular seals are sometimes beaded before sealing into a glass envelope, particularly in the case of small cup terminals and similar designs which often are inside-outside seals. Metals which have a protective coating of Cr_2O_3, such as chrome iron, Sylvania No. 4, etc., do not require beading to prevent formation of oxide.

With hard glasses beading is advisable because the working temperatures of these glasses are high. Even with oxygen-hydrogen fires there is danger of leaky seals because of the high surface tension of the glasses.

36. King, R. M., *Glass Ind.*, **23**, 421 (1942).
37. Weyl, W. A., *Glass Ind.*, **26**, 557 (1945).
38. Spencer-Strong, G. H. and King, R. M., *J. Amer. Ceram. Soc.*, **13**, 208-14 (1934).
39. *U. S. Patent* 2,192,892 (March 12, 1940)

converted to the atomic or molecular form. The less probable this electron transfer, the more stable is the colorless ionic silver. Phosphate glasses are notably protective toward silver ions because of the stability of the phosphate group.

In general, the formation of color producing silver aggregates from the colorless ion is favored by reducing atmosphere, reducing agents, alkaline base glass and high melting temperature. The base glass also affects the solubility of metallic silver and the complex phenomena observed correspond entirely to those which Dr. Weyl extensively discusses in the case of gold.

Silver Stain

The process of baking a vitreous surface coated with a mixture containing silver and clay or ochre in order to produce a color in this surface has been known for over a thousand years. The process involves the exchange of the alkali ions of the base glass with the silver ions in the coating. In the glass the silver ions are reduced to silver atoms which aggregate into small silver crystals imparting color to the surface coating.

Only two ions, silver and copper, are capable of staining glass in this manner. In the case of copper, reduction cannot be accomplished without the aid of a reducing atmosphere.

The concentration of silver in the paste ranges between 5 and 20 per cent, the temperature of the ware, e.g., 550° C., although lower temperatures may suffice. The silver compound usually is the oxide, carbonate, sulfate, or sulfide. The silver in the paste must be in the form of ions, as metallic silver is incapable of migrating into the rigid glass.

In the underlying chemical reaction the glass may be treated like a sodium ion and a huge anion, and one may write:

$$Na^+ - glass^- + Ag^+Cl^- = Ag^+ - glass = + Na^+Cl^-$$

The depth to which the coloration enters from the surface into the glass depends upon the diffusion of the silver ions into the glass, a process which takes place with comparative ease. The diffusion shows the usual dependence on temperature and gradient of concentration, the initial concentration at the surface being also dependent on the nature of the silver compound used.

The clay or ochre contributes to the process by its capacity of binding the alkali released from the glass.

Sodium glasses seem to take the stain better than potassium glasses, but in general the oxidizing or reducing power of minor constituents Sb_2O_3, As_2O_3 and Fe_2O_3 is more important than the base glass composition. The silver stain has had applications outside the field of decoration. It has been used by W. Weyl and J. G. Turnbull to make striae visible.

The strengthening of the glass surface by the exchange of sodium with silver ion without subsequent reduction, which might be called an undeveloped silver stain, was proposed by F. L. Jones.

Elemental Copper

Nature of the Color. As in the case of silver and gold, elemental copper causes the coloration of copper ruby glasses, in variation depending upon the size of the color-

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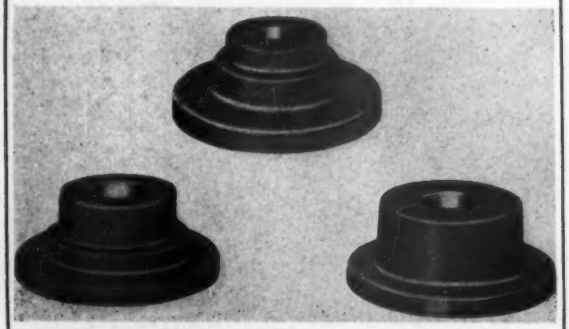

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ing aggregates. The chemistry of copper glasses, however, is complicated by the fact that the ions Cu^{+} and Cu^{++} also can appear and cause various colorations; these were discussed in a previous section. If the red colors based on elemental copper are to be produced, the appearance of the ionic colors is classed as a defect.

The colors caused by elemental copper in different states of subdivision are classified as follows: (1) The transparent red copper ruby, containing copper crystals of colloidal size. (2) The opaque red hematinone, containing copper particles of the order of magnitude of the wave length of visible light. (3) The aventurine, containing glittering crystals of copper, .5 to 1 mm in size. (4) Copper stain, a transparent red color in the surface layer of glass introduced by the migration of copper ion from copper compounds into the finished glass and their subsequent reduction to elemental copper.

The first type, copper ruby, corresponds to gold ruby and yellow silver glass, the second and third, hematinone and aventurine, to certain variations of gold and silver glasses which are often undesirable, and the fourth, copper stain, to the silver stain. The noble character of gold accounts for the absence of a gold stain based on the migration of ions.

The copper ruby is commercially important; the application of the copper stain is limited; and the use of hematinone and aventurine is historical.

The concentration of copper in ruby glass is about 1 per cent, in hematinone 10 per cent and in aventurine 5 per cent.

Only on heating do the colors of all these types appear from a colorless condition which corresponds to solution in atomic subdivision. Copper rubies require reducing conditions and, frequently, the presence of tin. Copper stain, unlike silver stain, requires a second, reducing fire. The red colors obtained with elemental copper are very dark. The absorption is maximal at about 550, minimal at about 690 $m\mu$.

Base Glass. The influence of the base glass is caused by the varying solubility of copper in various base glasses, the varying change of the solubility of copper with temperature and the closely related influence of viscosity on these conditions. Lead glasses have a higher solvent power for copper than soda lime glasses. However, copper ruby has been made from Fourcault glass.

Tin Oxide and the Reduction of Copper Oxide. Up to the most recent time, about 1 per cent tin oxide has been considered essential for the formation of copper ruby. Copper is used significantly in the analytical borax bead test for tin. Tin oxide is usually referred to as a reducing agent for copper oxide; however, according to Dr. Weyl this assumption is very doubtful. SnO_2 is more effective than SnO, and other reducing agents are by no means effective.

The equilibrium of the three steps of oxidation of copper:

$$Cu — Cu^{+} — Cu^{++}$$

is not well understood. It seems certain that the decomposition of Cu^{+} compounds does not lead to Cu alone, but to Cu and Cu^{++}. Cu^{++} causes red absorption and the green absorption interferes with the brilliancy of the red ruby glass.

Sulfur, phosphorus and the cyanides appear to dispose of the excessive Cu^{++}, and the operation with cyanides has been reported to be particularly successful.

Other additions which have been proposed to steer the process in the desired manner are silicon, antimony and silicon carbide.

Reheating. The influence of reheating is treated extensively by Dr. Weyl. The range of most favorable reheating temperatures for obtaining pure red colors is narrow. At too high temperatures the solubility is high and the development of color, i.e., "striking," ceases. The transition ranges lead to impure colors because of size of aggregation. At low temperatures reheating times become very long and, again, color deviations are observed.

Copper Stain. Unlike the age-old silver stain, copper stain is a recent invention of Bohemia (1832). The process is more complicated than that of silver staining because the red color appears only if a second, reducing fire is applied. The variety of potash glass produced in Bohemia, happens to be best suited for the base exchange of alkali and copper ions upon which the process is based. The copper ions migrate from a slip of iron oxide and gum arabic, containing copper oxide in a concentration of about 25 per cent.

N. J. Kreidl

CORNING MAKES SECOND-QUARTER REPORT

Earnings of $553,695, equal to 19 cents a share for the second quarter of 1946, were reported by the Corning Glass Works. These amounts compare with $529,970, or 18 cents a share for the same period in 1945.

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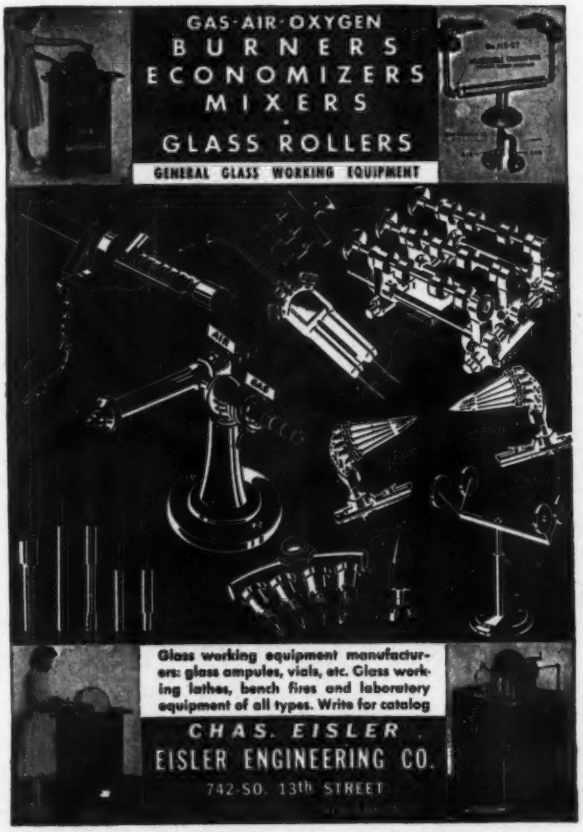
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